

# THORACIC CIRRIPEDIA FROM GUYOTS OF THE MID-PACIFIC MOUNTAINS

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**ABSTRACT.**—Knowledge of the fauna of oceanic seamounts is meager. To determine whether seamounts serve as stepping stones for the distribution and dispersal of sedentary faunas across oceanic barriers, and their role in the biogeography and speciation of deep-sea faunas, an expedition went to the Mid-Pacific Mountains in the summer of 1968. This paper reports on Thoracic Cirripedia from six guyots located there.

Nine species were identified, of which four are new. Three of the new species are allied to forms from the Indo-Pacific; the fourth is closely related to a Hawaiian species. Of the five previously known species, two are widely distributed in the Indo-Pacific, two are cosmopolitan and one is endemic to Hawaii. Thus, the affinities of the cirripeds are predominantly Indo-Pacific.

Virtually nothing is known of the faunas of submarine archipelagos. One would like to know specifically what role seamounts serve as stepping stones at bathyal depths, what importance they have in the evolution of deep-sea faunas, and to what degree these faunas tend to be endemic. In the summer of 1968, William A. Newman and Richard H. Rosenblatt, both of the Scripps Institution of Oceanography, John A. Allen of the Dove Marine Laboratory, England, and the late Edwin C. Allison of San Diego State College, and Harry S. Ladd of the U.S. Geological Survey staged an expedition (Styx-Leg 7) aboard the *R/V Alexander Agassiz* to investigate both recent and extinct faunas of the Mid-Pacific Mountains.

The Mid-Pacific Mountains are a chain of seamounts located between 17° and 23°N, with the main axis extending between 165°W and 170°E for some 2,780 km (Fig. 1). This chain of seamounts, part of the Marcus-Necker Ridge, forms the northeastern portion of the region designated as the Darwin Rise (Menard, 1964). Numerous flat-topped seamounts occur along this chain at depths ranging between approximately 1,000 and 1,700 m. Shallow water megafossils taken by dredging indicate that many flat-topped seamounts are guyots, land forms produced by subaerial erosion and marine planation at a time when they broke the sea surface. The fossils, particularly the rudist molluscs and associated organisms such as corals, indicate that the seamounts persisted as shallow water banks and reefs up to the mid-Cretaceous before subsiding more than a kilometer to their present depths (Hamilton, 1956). Prior to this time, the Mid-Pacific Mountains formed an extensive island chain, comparable to the present Hawaiian Archipelago. Since formation, the chain has migrated northwest some 25° to its present position (Lonsdale *et al.*, 1972). Consequently the chain has always been beneath tropical waters.

The tops of the guyots have been altered to varying degrees since they subsided (Karig *et al.*, 1970; Lonsdale *et al.*, 1972). Virtually all exposed hard surfaces, such as rudist reefs, limestone, exhumed chert and basalt outcrops are covered with ferromanganese oxides of varying thickness. For some reason fresh manganese-coated surfaces appear unfavorable for attachment of benthic organisms and the numerous large slabs and nodules dredged from the Mid-Pacific Mountains were devoid of them. Generally pieces of pumice, apparently of recent origin, and occasional small rocks (cherts) are free of manganese coatings. Otherwise, uncoated hard surfaces on which sedentary organisms might be expected to settle and attach are limited to the hard parts of living organisms such as spicules of siliceous sponges, shells of gastropods, barnacles and corals usually occurring on soft sediments. In the present collection cirripeds were taken from all these with the exception of the corals.

Sampling methods were varied. Pipe and chain-bag dredges were employed on hard bottoms and outcrops; otter and beam trawls over soft bottoms. A variety of benthic invertebrates was recovered and the present paper reports on the class Cirripedia. Only mem-

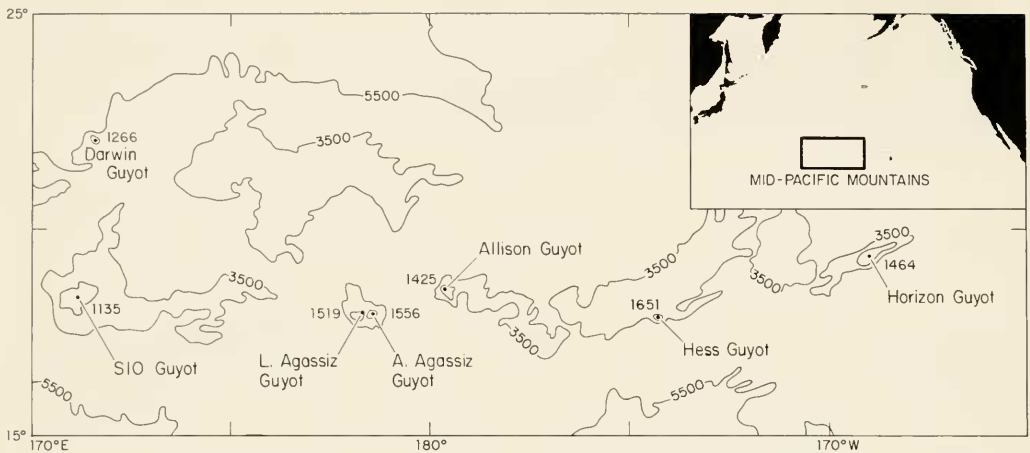


Figure 1. Chart indicating the location of the guyots sampled on the Mid-Pacific Mountains during the Styx-7 Expedition. Depths in meters. Numerous other guyots in the region not indicated. Of the guyots indicated, only Darwin, Hess and Horizon have been named previously.

bers of the order Thoracica were encountered on the six guyots sampled (Table 1). (Station numbers for this leg of the expedition were numerical: year, month, day, 1, 2 or 3 etc.).

Of the nine identifiable species found, four are new, the relative number of new species being comparable to that of the Antarctic (Newman and Ross, 1971). One cannot assume that all four new species from the Mid-Pacific Mountains are endemic to the region because knowledge of deep-sea cirripeds is meager (see Zevina, 1972). While one of the new species is most closely related to a species known previously only from Hawaii, the remaining three show close affinities with forms widely distributed in the Indo-Pacific. Of the five previously known species, two are known from the Indo-Pacific, one from Hawaii (and thus perhaps an Indo-West Pacific derivative endemic to Hawaii), and two are cosmopolitan. Thus, as one might have anticipated, the affinities of the cirriped fauna of the Mid-Pacific Mountains are primarily with the Indo-Pacific. The fishes show comparable affinities (R.H. Rosenblatt, pers. comm.).

While virtually nothing is known of the faunas of other submarine archipelagos, the fauna of Shoal Guyot, situated at approximately 25° S, 85° W, some 1,300 km west of South America at a depth of 288 m, is relatively well known and is of considerable biogeographic interest. Hubbs (1959) published on fishes, and information on echinoderms and barnacles was given by Zullo *et al.* (1964), Zullo and Newman (1964) and Allison *et al.* (1967). One might have expected the fauna of Shoal Guyot to be strongly Eastern Pacific in character since it is separated from the Indo-Pacific by the so-called East Pacific Barrier. To the contrary however, it proved to be primarily an eastward extension of the Indo-West Pacific and thus would appear to be the eastern terminus of a series of submarine stepping stones at bathyal depths across the East Pacific Barrier (Allison *et al.*, 1967). The situation is more complicated than this however, for there is apparently a peculiar extension of neretic plankton toward this region from the west (A. Fleminger, pers. comm.), and this indicates that the eastward extension of the Indo-Pacific fauna is not simply by way of submarine stepping stones in this region, as previously supposed.

#### SYSTEMATIC ACCOUNT

Order Thoracica Darwin, 1854  
 Suborder Lepadomorpha Pilsbry, 1916  
 Family Scalpellidae Pilsbry, 1916  
 Genus *Arcoscalpellum* Hoek, 1907

*Arcoscalpellum alcockianum* (Annandale), 1905

Figures 2 and 11G

*Scalpellum alcockianum* Annandale, 1905:82; 1906a:138; 1906b:392; 1913:229; 1916:129, pl. vi, fig. 5; Calman, 1918a:115; Nilsson-Cantell, 1928 :6; 1931:2; 1938:7.

Table I. Cirripedia from guyots of the Mid-Pacific Mountains

Species	Horizon	Hess	Allison	Agassiz	Sio	Darwin	Previously known distributions	Sources
LEPADOMORPHA								
Family: Scalpellidae								
1. ? <i>Arcoscalpellum</i> sp.					1718m			Present report
2. <i>Arcoscalpellum alcockianum</i>			1418–1664m				Indian Ocean; Mozambique Channel; Gulf of Manaar; Bay of Bengal; Malay Archipelago; SW Pacific Ocean; (1098–1800m)	Annandale (1906); Calman (1918a); Nilsson-Cantell (1938)
3. <i>Arcoscalpellum elegantissimum</i> n. sp.	1652–1670m			1566m			Lukunor Atoll, Caroline Islands; (972m) (present report)	Present report
4. <i>Arcoscalpellum hawaiiense</i>			1415–1557m				Hawaii; (1460m)	Pilsbry (1907a)
5. <i>Arcoscalpellum michelottianum</i>	1584–1800m	1692–1735m	1413–1645m	1557m			Cosmopolitan – Atlantic, Indian, Pacific and Antarctic Oceans; (40–2900m)	Nilsson-Cantell (1938); Newman and Ross (1971)
6. <i>Arcoscalpellum radiatum</i>	1584–1800m		1413–1645m					Present report
7. <i>Arcoscalpellum rossi</i> n. sp.		1692–1735m	1413–1645m					Present report
8. <i>Mesoscalpellum gruvellii</i>			1429–1663m				Indian Ocean; Gulf of Aden; Laccadives; Gulf of Manaar; Andaman Sea; (794–2268m)	Nilsson-Cantell (1938)
Family: Pencilasmatidae								
9. <i>Megalasma (Glyptelasma) pilsbryi</i>			1445–1557m				Indian Ocean; Malay Archipelago; Pacific and Atlantic Oceans; (1098–1647m)	Nilsson-Cantell (1938)
VERRUCOMORPHA								
10. <i>Verruca (Altiverruca) allisoni</i> n. sp.		1718–1770m	1413–1645m			1300–1353m		Present report

*Material*.—Styx-7, 680903-04 Sta. 1, Allison Guyot (18°31'N, 179°36'W), 1418–1664 m (otter trawl). One hermaphrodite on long glassy spicules of a siliceous sponge.

*Supplementary description* (hermaphrodite).—The capitular plates were adequately described by Annandale (1906b). Evidently the capitulum and the peduncle are subject to considerable variation (Annandale, 1913; Nilsson-Cantell, 1928). In the present specimen as compared to those shown by Annandale (1916), tergum is not as reduced, the scutal margin is hollowed out, and the carinal margin is angular and recedes from the carina both above and below. The scutum is not fully calcified, and the calcified portion is triangular, reaching to the lower extremity of the occludent margin of the tergum; the apex is terminal. A rostrum is present.

The peduncle is cylindrical, almost as high as the capitulum and armed with about 13 rows of transversely elongate plates. There is no basal disc in the present specimen, apparently reflecting the substrate to which the specimen is attached.

Of the arthropodal structures brief descriptions were given by Annandale and Nilsson-Cantell together with figures of the mandible, maxillae and caudal appendages. The following account and accompanying figures are supplementary.

Labrum bullate, very broad distally and mottled by pigment all over the surface; teeth very small; palp elongate, pointed at the tip and covered with plumose spines along the entire margin (Fig. 2D). Maxilla I having nearly straight cutting edge divided into two steps with about 13 strong spines above, and approximately 10 strong and 18 weaker spines of about equal length below (Fig. 2E). Maxilla II large, with superior margin long, supporting a continuous row of spines; a medial notch as noticed by Nilsson-Cantell (1928); maxillary lobe short, broad and truncate apically (Fig. 2F). Mandible with four teeth including inferior angle; first tooth well separated from second, third tooth nearer to inferior angle than to second (Fig. 2B); inferior angle supporting 30–31 short blunt subspatulate spines some of which are bifid (Fig. 2C).

Cirrus I widely separated from the rest; intermediate segments of the anterior ramus strongly protuberant, those of the posterior ramus cylindrical and 2/3 as wide; both rami prominently hairy (Fig. 2A). Cirrus II nearly 1½ times as long as cirrus I and cirrus III a little longer than the second. Cirri V and VI with terminal segments missing. Segment 18 of cirrus VI is figured (Fig. 2G); articular areas along greater curvature with 2–4 long and 1–2 short setae; lateral faces with a few short setae; interarticular areas devoid of setae and bristles. Setation ctenopod; four major pairs of setae along lesser curvature. Between each

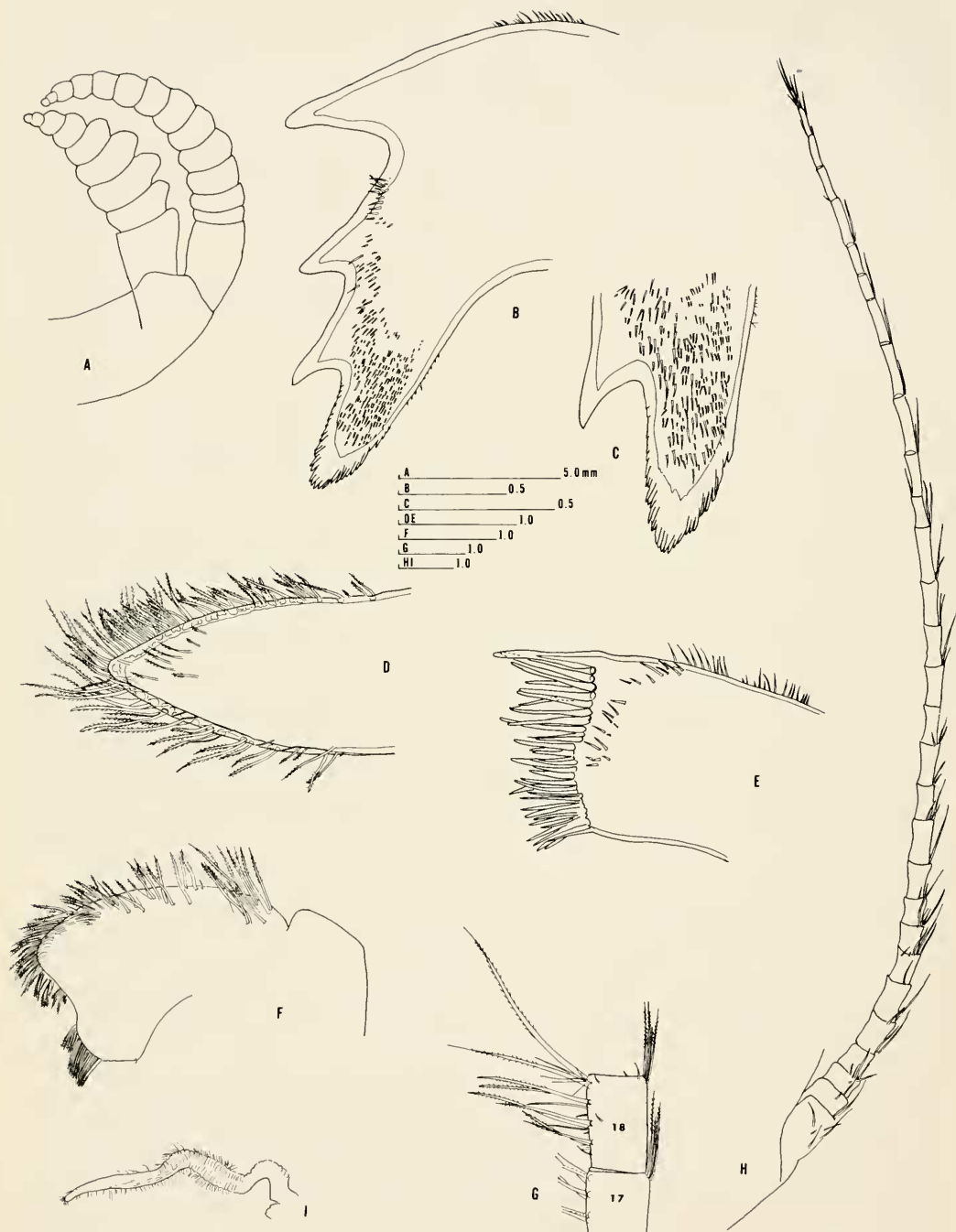


Figure 2. *Arcoscalpellum alcockianum* (Annandale), Styx-7, 680903-04 Sta. 1. A, cirrus I; B, mandible; C, third tooth and inferior angle of mandible; D, palp; E, maxilla I; F, maxilla II; G, intermediate articles of cirrus VI; H, caudal appendage; I, penis.

major pair there are 1-2 long bristles. Caudal appendage of 29 segments reaching to at least half the length of cirrus VI. Each segment with 1-5 setae along outer margin, terminal segment with a tuft of 5 short setae at tip (Fig. 2H).

Penis short, moderately stout, covered with small hairs and annulated in the proximal part; distal end narrow and covered with minute hairs (Fig. 2I).

Two complementary males were recovered, one from each pouch near the tip of the in-

side of each scutum. The male is sac-like, without traces of valves or cirri, but the mantle is covered with rows of spines and supports two prehensile antennae at the middle of the ventral margin.

*Remarks.*—This species is apparently distributed widely in the Indian Ocean, having been reported several times from the Bay of Bengal and Malay Archipelago. The only record outside of this area is in an unpublished report by Calman on specimens taken between Australia and New Zealand (Nilsson-Cantell, 1928). The present report extends its range far east into the Pacific.

*Arcoscalpellum giganteum* (Gravel) from the Atlantic is closely related, but its tergum is much hollowed and the caudal appendage consists of only four segments.

### ***Arcoscalpellum elegantissimum* n. sp.**

#### **Figure 3**

*Material.*—Styx-7, 680907 Sta. 1, Agassiz Guyot (17°50.6' N, 178°25.0' W), 1566 m (otter trawl) 1 spec.; 680829 Sta. 3, Horizon Guyot (19°28.0' N, 168°52.3' W), 1652-1670 m (rock dredge), 1 spec.; CARMARSEL Exped. Sta. 815 (off Lukunor Atoll, Caroline Islands, 10 March 1967), 972 m, 2 spec.

*Depository.*—U.S.N.M. no. 140943 (Holotype, Styx-7, 680907, Sta. 1) U.S.N.M. no. 140944 (Paratype, Styx-7, 680829, Sta. 3, 1 spec.) U.S.N.M. nos. 140945, 140946 (CARMARSEL Exped. Sta. 815, 2 spec.)

*Diagnosis.*—Capitulum with 14 fully calcified approximate plates ornamented with strong radial ridges. Carina broad basally; carinal roof traversed by longitudinal ridges; parietes well developed. Carinal latus as broad as high. Rostral latus wider than high. Rostrum ovotriangular and fully exposed. Inframedian latus higher than rostral latus but shorter than carinal latus. Mandible with 4 teeth including inferior angle. Maxilla I with straight cutting edge. Intermediate segments of cirrus VI with 2-3 major and 1 minor pair of setae. Caudal appendages with 4 partially fused segments reaching  $\frac{3}{4}$  the length of first segment of pedicel of cirrus VI.

*Description (female).*—Capitulum globose, ovally elongate, apically pointed, hirsute especially on the carinal side; 14 fully calcified plates, white, with no indication of a persistent cuticle. Plates ornamented with prominent ridges, radiating from the umbones, intersected by faint growth lines (Fig. 3A).

Tergum nearly twice the area of the scutum, rhomboid, twice as long as wide; apex prominently acute; basicarinal angle reaching about  $\frac{3}{4}$  the distance towards the base of the capitulum, nearly to the lower whorl of the plates; lateral margin partly overlapped by the upper latus. Scutum subquadrate, more than twice as long as broad; surface convex, appearing divided into halves by a diagonal angulation running from the umbo to the basilateral angle. Carina strongly bowed, broad basally, tapering towards apex; roof essentially flat, traversed by prominent longitudinal ridges; parietes well developed and also prominently ridged. Carinal latera meet for a short distance at base of carina forming a broad V-shaped margin (Fig. 3B); each as broad as high, with an inwardly curved apex which projects slightly beyond the surface of the capitulum; basal and lateral margins irregular; two ledges running from umbo to base divide plate into two parts, a shallow wing-like expansion at base of upper latus and two triangular areas (one a raised carinal part adjoining the carina and the other a concave middle portion between this and the wing-like portion). Inframedian latus triangular, slightly higher than broad; apex raised above the surface of capitulum and curved inwards. Rostral latus twice as broad as high; scutal and basal margins subparallel; plate diagonally divided into halves by a faint ridge; apices of both sides partly overlapped by rostrum (Fig. 3C). Rostrum ovotriangular, broad at anterior end and narrow posteriorly (Fig. 3C). Peduncle short,  $\frac{1}{4}$  height of capitulum and armored with 8-10 rows of 4-5 closely packed, narrow and elongate scales. Measurements (in mm) of the holotype follow: overall height, 16.5; height of capitulum, 13.0; height of peduncle, 4.0.

Labrum bullate, no soft setae present; crest armed with about 45 teeth. Palp elongate, triangular, somewhat rounded distally; proximal superior margin with short stiff bristles; distal border with long setae (Fig. 3H). Mandible with four teeth including inferior angle; second tooth well separated from first (Fig. 3D); inferior angle with 13-15 triangular to subspatulate teeth a few of which are bifid (Fig. 3E). Maxilla I with cutting edge feebly concave above and convex below; concave part supports 2 long, stout and 3-4 shorter, thinner spines (Fig. 3F). Maxilla II triangular in shape, lobes weakly developed; marginal setae dis-

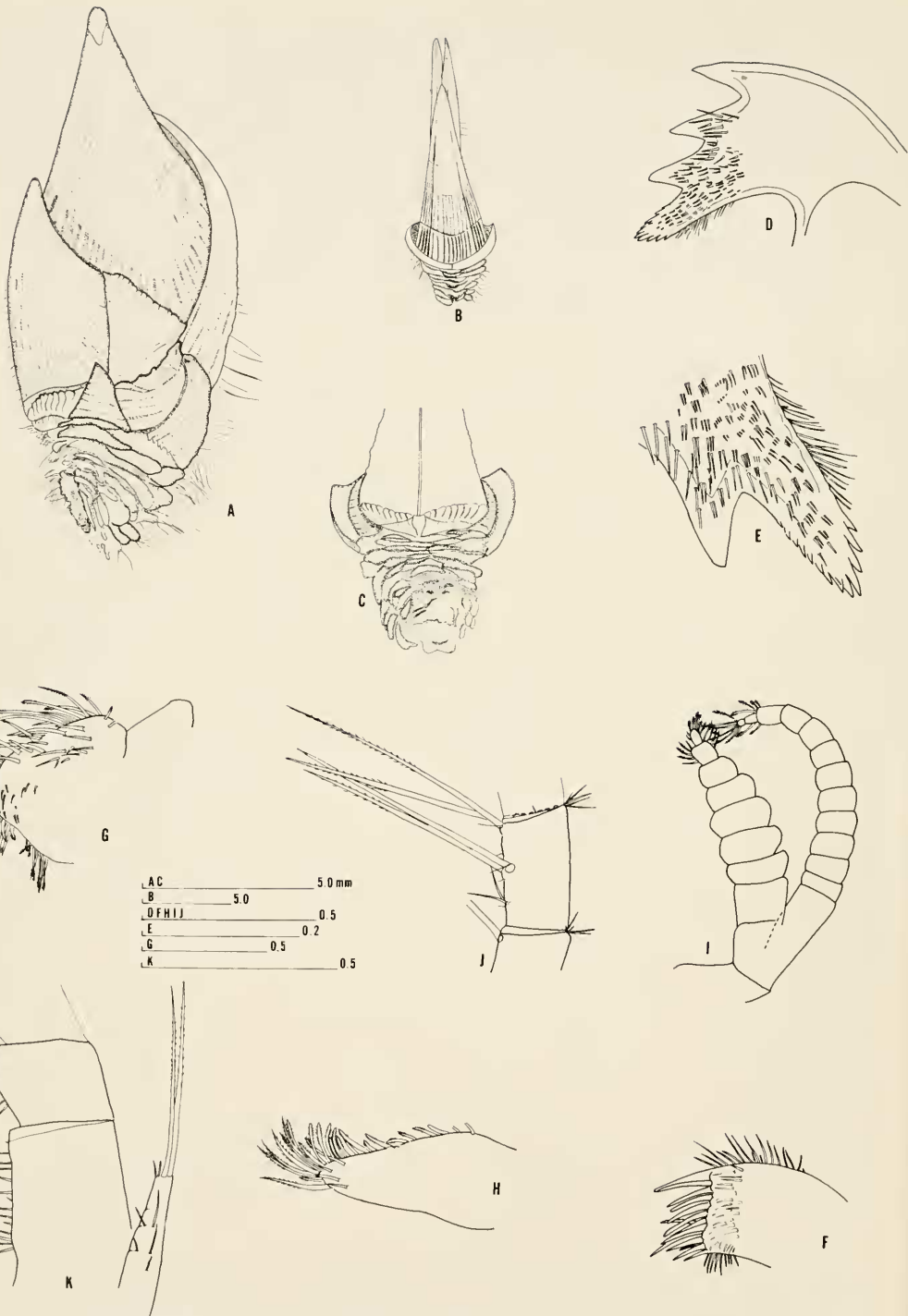


Figure 3. *Arcoscalpellum elegantissimum* n. sp., Holotype, Styx-7 680907 Sta. 1, Agassiz Guyot. A, side view of female; B, carinal view; C, rostral view; D, mandible; E, third tooth and inferior angle of mandible; F, maxilla I; G, maxilla II; H, palp; I, cirrus I; J, intermediate articles of cirrus VI; K, caudal appendage.

tributed in three clusters, but those of the superior and distal borders are contiguous; maxillary lobe short, broad and truncate apically (Fig. 3G).

Cirrus I well separated from the rest; anterior ramus shorter than posterior; intermediate segments of anterior ramus protuberant, those of posterior cylindrical and  $\frac{3}{4}$  as

wide; both rami clothed with long setae (Fig. 3I). Cirrus II normal. Cirri IV-VI nearly equal in length with equal or sub-equal rami. Each articulation along greater curvature of intermediate articles of Cirrus VI supporting 4-5 short slender setae. Interarticular areas along greater curvature and lateral faces free of setae. Setation ctenopod; 2-3 major pairs and 1 minor pair with 1-2 slender spines at bases of major setae (Fig. 3J). Caudal appendage composed of 4 stout, partially fused segments, extending about  $\frac{3}{4}$  length of pedicel of Cirrus VI; distal article with tuft of 3-5 setae, 2 or 3 being longer than appendage (Fig. 3K). Cirral counts of the four specimens follow:

	I	II	III	IV	V	VI	Ca
Styx-7 680907	$\frac{8}{12}$	$\frac{22}{20}$	$\frac{22}{21}$	$\frac{24}{25}$	$\frac{25}{17+}$	$\frac{25}{26}$	4
Sta. 1							
Agassiz Guyot (Holotype)	$\frac{8}{13}$	$\frac{21}{22}$	$\frac{22}{24}$	$\frac{21}{25}$	$\frac{22}{24}$	$\frac{26}{26}$	4
Styx-7 680829	$\frac{7}{12}$	$\frac{20}{20}$	$\frac{23}{23}$	$\frac{25}{22}$	$\frac{15+}{23}$	$\frac{25}{23}$	3
Sta. 3 (Paratype)							
	$\frac{7}{12}$	$\frac{20}{20}$	$\frac{22}{23}$	$\frac{13+}{23}$	$\frac{23}{23}$	$\frac{23}{23}$	3
CARMARSEL Sta. 815 (Paratype)	$\frac{8}{12}$	$\frac{20}{20}$	$\frac{22}{21}$	$\frac{22}{22}$	$\frac{24}{24}$	$\frac{25}{25}$	4
	$\frac{7}{12}$	$\frac{16+}{19}$	$\frac{21}{21}$	$\frac{22}{22}$	$\frac{16+}{23}$	$\frac{12+}{23}$	4
CARMARSEL Sta. 815 (Paratype)	$\frac{7}{9}$	$\frac{15}{15}$	$\frac{16}{15}$	$\frac{16}{15}$	$\frac{17}{17}$	$\frac{17}{17}$	2
	$\frac{7}{9}$	$\frac{14}{14}$	$\frac{15}{15}$	$\frac{16}{18}$	$\frac{15}{17}$	$\frac{17}{18}$	2

*Remarks.*—*Arcoscalpellum elegantissimum* is closely related to the *A. michelottianum* group of scalpellids (Newman and Ross, 1971). Important uniting characters are: a prominently hirsute capitulum, a triangular inframedian latus not exceeding the height of the carinal latus and with an apical umbo, carinal lateral plates not interdigitating where they meet below the carina, and a rostral latus almost twice as wide as high. The new species is closely allied to *A. hawaiiense* (Pilsbry) but differs in having: 1) apex of carinal latus curved inwards, not projecting beyond the base of the carina; 2) posterior ramus of cirrus I only slightly longer than the anterior ramus but with  $1\frac{1}{2}$  times as many segments; 3) caudal appendage with but four incompletely fused segments and less than the height of the first segment of the pedicel; 4) scales on the peduncle not overlapping or imbricating and 5) a much smaller size. In its small size and the general nature of the arthropodal structures *A. elegantissimum* shows some resemblance to *A. hirsutum* (Hoek). However, in the latter species the roof of the carina does not possess longitudinal ridges and the carinal latus is less elaborately developed.

The specific name refers to the elegant capitular ornamentation.

*Arcoscalpellum hawaiiense* (Pilsbry), 1907  
Figures 4 and 11 C-D

*Scalpellum hawaiiense* Pilsbry 1907a: 181, pl. IV, fig. 1-2.

*Material.*—Styx-7, 680905 Sta. 2, Allison Guyot (179°37.1' W, 18°35.4' N) 1450-1557 m (otter trawl), 1 spec. attached to a small rock.

*Supplementary description* (female).—The capitular structure of this scalpellid agrees well with the description of the type from Kauai, Hawaii (Pilsbry, 1907a). The present specimen, larger than the type, has the following dimensions (in mm): overall height, 44; capitular height, 31; width of capitulum, 22; height of peduncle, 14.

The arthropodal structures were not described and are dealt with here. Labrum bulate, longer than broad, apex gently curving, surface mottled with pigment. Palp long and narrow, superior and anterior margins clothed with thick, short, slightly plumose setae; an-

terior margin and lateral faces naked (Fig. 4F). Mandible with 4 teeth including inferior angle; teeth more or less equidistantly spaced (Fig. 4B); inferior angle supporting about 14 teeth many of which are worn and blunt (Fig. 4C). Maxilla I with cutting edge nearly straight without evident notch; upper half supporting 7 spines, the uppermost 2 long and stout, the rest shorter and thinner; lower portion supporting 17-18 long and short spines (Fig. 4D). Maxilla II triangular, with 3 weakly developed lobes; marginal setae distributed in three clusters, those of superior and anterior margins being longer; lateral faces devoid of setae (Fig. 4E).

Cirrus I widely separated from the rest; posterior ramus  $1\frac{1}{2}$  times longer than anterior ramus; intermediate segments of anterior ramus strongly protuberant, those of posterior ramus cylindrical and  $\frac{2}{3}$  as wide (Fig. 4A). Cirrus II normal. Cirri III-IV about equal in length with equal or subequal rami. Each articulation along greater curvature of intermediate segments of cirrus VI with a cluster of 2-5 short setae. Setation ctenopod; 3 major pairs of setae along lesser curvature, a pair of long slender setae at base of distal pair and 2-3 short bristles at bases of all major pairs (Fig. 4G). Caudal appendage of six segments, each with 1-3 spines, reaching to about  $\frac{1}{2}$  length of second segment of pedicel of cirrus VI. Terminal segment with a tuft of 4 long and 2-3 short, slender setae (Fig. 4H). Cirral counts are as follows:

	I	II	III	IV	V	VI	Ca
Styx-7 680905 Sta. 2	$\frac{9}{17}$	$\frac{28}{27}$	$\frac{33}{32}$	$\frac{32}{32}$	$\frac{36}{34}$	$\frac{40}{40}$	6
	$\frac{9}{17}$	$\frac{28}{28}$	$\frac{30}{32}$	$\frac{33}{34}$	$\frac{34}{36}$	$\frac{40}{40}$	6

Eight dwarf males were recovered, four from each pouch on the inside of the distal end of the scutal plates. The males are sac-like, devoid of plates but covered with rows of spines.

*Remarks.*—This is the second report of *A. hawaiiense* which was originally dredged off Kauai, Hawaii at a depth of 1460 m. Though Pilsbry (1907a) did not describe the mouth parts and cirri, the capitular structure of our specimen agrees almost point for point with the description of the type specimen. The bathymetry also agrees. Pilsbry drew attention to the relationship between *A. hawaiiense*, *A. rubrum* (Hoek) and *A. hirsutum* (Hoek). In a later publication he (Pilsbry, 1911) included these species under the group of *Scalpellum velutinum*. With this we concur. However, a detailed comparison of *A. hawaiiense* from Allison Guyot with more complete descriptions of *A. rubrum* (Pilsbry, 1911) and *A. hirsutum* (Newman and Ross, 1971) shows that the resemblance is rather superficial, there being several differences in the capitular structure, mouth parts and cirri. *Arcoscalpellum hawaiiense* shows close resemblance to *A. elegantissimum* n. sp. While closely related, these can be distinguished from one another by the following characters; *A. hawaiiense* has 1) the apex of the carinal latus projecting, though slightly, away from the carina; 2) close and imbricating scales of the peduncle; 3) posterior ramus of cirrus I,  $1\frac{1}{2}$  times longer than the anterior and composed of nearly double the number of segments, 4) a caudal appendage composed of 6 segments and reaching to about  $\frac{1}{2}$  the length of second segment of the pedicel of cirrus VI, and 5) a much larger overall size.

*Arcoscalpellum wyethi* (Cornwall) from Guam appears to be a related form, but in this species the carinal latera project strongly beyond the base of carina, the scales on the peduncle do not overlap and are widely spaced, and the intermediate articles of cirrus VI support 5 pairs of setae instead of 3 pairs as in *A. hawaiiense*.

*Arcoscalpellum michelottianum* (Seguenza), 1876

Figures 5 and 11 A-B

*Scalpellum michelottianum* Seguenza, 1876:381, pl. 6, figs. 15-25; 464, pl. 10, fig. 26; *Arcoscalpellum michelottianum*: Newman and Ross, 1971: 71, pl. IXB, text-fig. 34 (see this reference for complete synonymy of this species).

*Material.*—Styx-7,680901 Sta. 3, Hess Guyot (174°24.8' W; 17°53.2' N), 1692-1735 m (Sigsbee beam trawl), 1 spec.; 680903-04 Sta. 1, Allison Guyot (179°36.0' W; 18°31.0' N), 1413-1645 m (otter trawl), 2 spec.; 680905 Sta. 2, Allison Guyot (179°37.1' W; 18°35.4' N), 1413-1449 m (otter trawl), several spec.; 680907 Sta. 4, Agassiz Guyot (178°14.2' W; 17°58.5' N), 1557 m (Sigsbee beam trawl), 1 spec.

*Supplementary description* (female).—The large series of specimens agree closely with



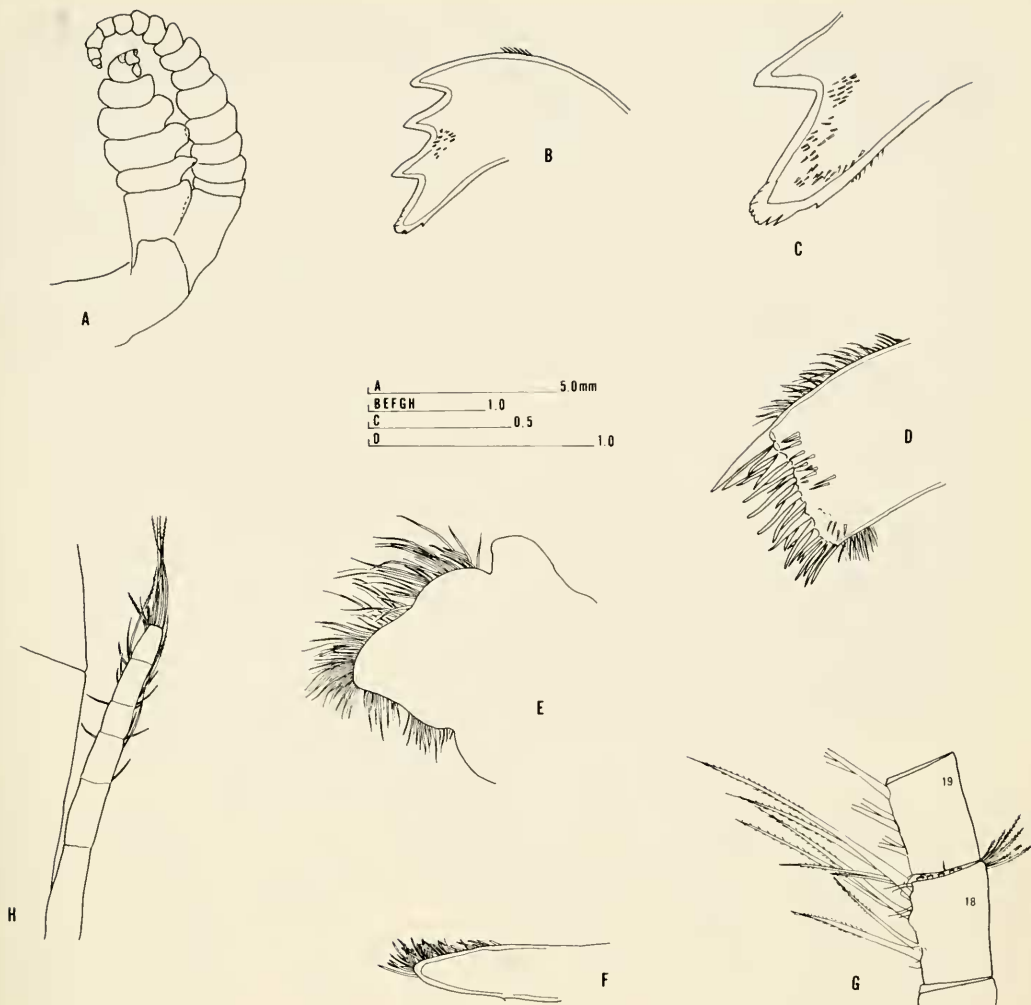


Figure 4. *Arcoscalpellum hawaiiense* (Pilsbry), Styx-7, 680905, Sta. 2, Allison Guyot. A, cirrus I; B, mandible; C, third tooth and inferior angle of mandible; D, maxilla I; E, maxilla II; F, palp; G, intermediate articles of cirrus VI; H, caudal appendage.

the descriptions of *Scalpellum eximium* Hoek (= *Arcoscalpellum michelottianum*). The lengthy synonymy under *A. michelottianum* (see Newman and Ross, 1971) indicates that this species is not only variable but that also several species were confused with and included in it. Because of this it is important that the specimens from the Mid-Pacific be carefully characterized, for the synonymy problem will undoubtedly continue.

Capitulum robust, thick near the peduncle and flatter towards the apex; surface covered by a yellow to olive colored cuticle, velvety to touch, prominently hairy in young individuals and sparsely so in older ones; 14 fully calcified plates usually fully approximate, but in some specimens carina separated from others by a narrow chitinous interspace (Fig. 11B). Scutum trapeziform;  $1\frac{1}{2}$ -2 times as long as broad, divided into two parts by a faint diagonal ridge running from umbo to basilateral angle. Carina strongly bowed, narrow apically and gradually increasing in width towards base; roof gently convex and traversed by an indistinct longitudinal median ridge and marked by V-shaped growth lines; parietes well developed and sculptured with 4-6 distinct longitudinal ridges; base triangular and enters as a wedge between carinal latera (Fig. 11A). Carinal latus irregular; umbo at recurved apex which, in some specimens, is raised above surface of capitulum; plate divided into three parts by two ridges running from umbo to basal margin. Inframedian latus as high or slightly higher than wide; apex usually curved downwards. Form of plate

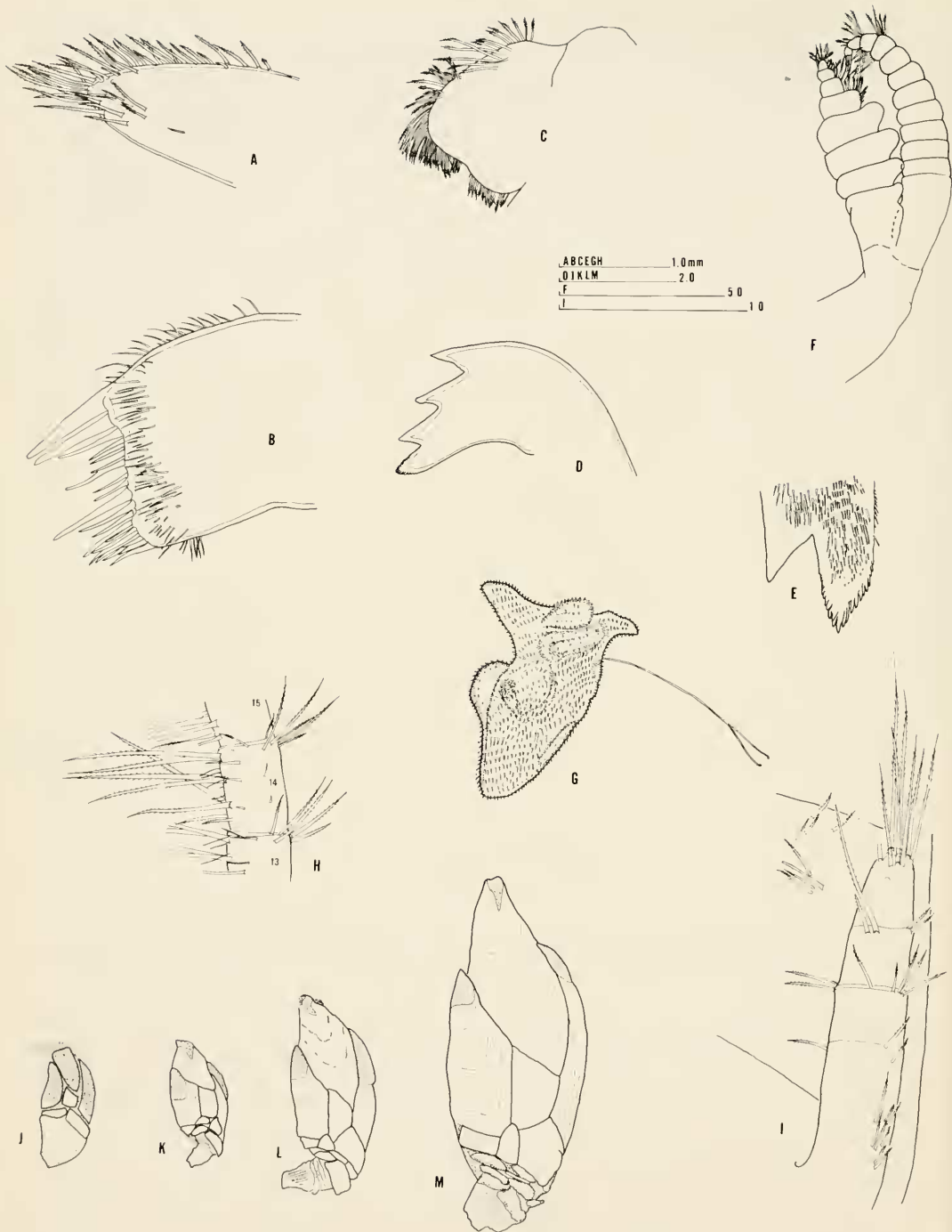


Figure 5. *Arcoscalpellum michelottianum* (Seguenza), Styx-7. 680901, Sta. 3, Hess Guyot. A, palp; B, maxilla I; C, maxilla II; D, mandible; E, inferior angle and third tooth of mandible; F, cirrus I; G, dwarf male; H, intermediate articles of cirrus VI; I, caudal appendage; J-M, side view of females.

changes considerably with growth (Fig. 5L-M). Rostral latus shorter than height of infra-median latus; broad and divided into two parts by a ridge running from umbo to lateral margin. Rostrum appearing externally in young individuals, lanceolate in shape; umbo apical. With growth, rostrum is overlapped by rostral latera of both sides and becomes hidden. Peduncle long; scales closely set or widely spaced, completely covered by a mem-

brane or partly projecting through it.

The measurements (in mm) of four dissected individuals are given below:

Station (Styx-7)	680901	680903-04	680903-04	680907
	Sta. 3	Sta. 1	Sta. 1	Sta. 4
Overall height	53	58	22	50
Height of capitulum	30	36	16	32
Height of peduncle	25	25	8	20

Labrum bullate; palp triangular, rather broad and short, superior and distal margins covered with long plumose spines, inferior margin naked (Fig. 5A). Maxilla I with cutting edge nearly straight; spines distributed in three indistinct sets; upper margin supporting 2 long stout and 5 short spines; intermediate set consisting of 1 long and 2 short spines; lower margin with a set of 1 long and 9-11 short spines (Fig. 5B). Mandible with four teeth including inferior angle; teeth spaced nearly equidistant from one another (Fig. 5D); inferior angle supporting 22-25 bluntly pointed teeth (Fig. 5E). Maxilla II broadly triangular, setae distributed in three clusters, those of superior and distal lobes contiguous; maxillary lobe broad, short and truncate apically (Fig. 5C).

Cirrus I widely separated from others; intermediate segments of anterior ramus strongly protuberant, those of posterior ramus moniliform and  $\frac{2}{3}$  as wide (Fig. 5F). Cirrus II normal, almost twice length of cirrus I. Cirri III-VI subequal with equal or subequal rami; articular areas along greater curvature have 3-4 long plumose setae; lateral faces with 2-5 rows of setae; setation ctenopod, three major pairs and one minor pair along lesser curvature; 2-3 short setae between major pairs (Fig. 5H). Caudal appendage of 4 incompletely fused segments, less than height of first segment of pedicel of cirrus VI; distally, articular areas with 2-4 spines on the outer margin; third segment with one long and one short seta on distal margin; distal segment with a tuft of 7-8 long plumose setae (Fig. 5I). Cirral counts of four dissected specimens follow:

	I	II	III	IV	V	VI	Ca
Styx-7 680901	$\frac{8}{13}$	$\frac{26}{29}$	$\frac{31}{30}$	$\frac{35}{25+}$	$\frac{18+}{20+}$	$\frac{17+}{16+}$	4
Sta. 3	$\frac{8}{13}$	$\frac{28}{27+}$	$\frac{30}{31}$	$\frac{35}{26+}$	$\frac{18+}{18+}$	$\frac{18+}{19+}$	4
Styx-7 680903-04	$\frac{8}{13}$	$\frac{26}{30}$	$\frac{30}{31}$	$\frac{35}{25+}$	$\frac{19+}{22+}$	$\frac{18+}{18+}$	4
Sta. 1 (spec. 1)	$\frac{8}{13}$	$\frac{28}{31}$	$\frac{30}{31}$	$\frac{35}{36}$	$\frac{36}{40}$	$\frac{15+}{13+}$	3
Styx-7 680903-04	$\frac{8}{11}$	$\frac{18}{21}$	$\frac{23}{22}$	$\frac{25}{24}$	$\frac{25}{23}$	$\frac{25}{23}$	2
Sta. 1 (spec. 2)	$\frac{8}{11}$	$\frac{19}{19}$	$\frac{23}{22}$	$\frac{20}{21}$	$\frac{24}{25}$	$\frac{25}{24}$	2
Styx-7 680907	$\frac{7}{13}$	$\frac{28}{27}$	$\frac{35}{28}$	$\frac{36}{32}$	$\frac{34}{35}$	$\frac{35}{33}$	4
Sta. 4	$\frac{7}{13}$	$\frac{29}{27}$	$\frac{32}{32}$	$\frac{31}{34}$	$\frac{37}{35}$	$\frac{35}{35}$	4

Dwarf males recovered from three large specimens; as many as 5-9 in a pouch on the inner sides of the scuta (Fig. 5G). They resemble those figured for *S. eximium* by Hoek (1883, pl. 9, fig. 10).

*Remarks.*—The Mid-Pacific specimens agree closely with Hoek's description of *Scalpellum eximium* and the resemblance is particularly striking with regard to the characteristic shape of the dwarf males.

The specimens from the Mid-Pacific differ from the examples of Newman and Ross (1971). The latter have a suprmedian notch in the cutting edge of Maxilla I where as none is apparent in the present specimens; the intermediate segments of cirrus VI have 4 pairs of setae in Pacific specimens as opposed to 3 pairs in the North Atlantic individuals. The *Elta-*

*nin* specimens, which are relatively small, came from depths exceeding 3000 meters while the specimens from the Mid-Pacific were dredged at nearly half that depth and are large. However, while it is possible that allometry and bathymetry account for the observed differences, it is also possible that the differences are genetic. There are presently insufficient data to resolve this problem.

### ***Arcoscalpellum radiatum* n. sp.**

#### Figure 6

*Material*.—Styx-7, 680903 Sta. 1 Allison Guyot (179°36.0' W, 18°31.0' N), 1413-1645 m (otter trawl), 2 spec.

*Depository*.—U.S.N.M. no. 140947 (Holotype, Styx-7, 680903 Sta. 1); U.S.N.M. no. 140948 (Paratype, Styx-7, 680903, Sta. 1).

*Diagnosis*.—Capitulum with 14 fully calcified approximate plates sculptured with prominent radial ribs emanating from the umbones. Carinal latera interdigitate at base of carina. Carinal roof flat, parietes well developed. Rostrum exposed, elongate triangular. Mandible with 4 teeth including a strongly denticulate inferior angle. Maxilla I with a deep medial notch in cutting edge. Caudal appendage uniarticulate and much shorter than first segment of pedicel of cirrus VI.

*Description* (female).—Capitulum elongate, oval, almost twice as long as broad; occludent and carinal margins moderately arched, covered with long hairs; 14 fully calcified approximate plates sculptured with prominent, evenly spaced ribs which extend from umbones to basal margins; ribs intercepted by feeble lines of growth (Fig. 6A). Scutum subquadrate; twice as long as broad and broadest in the middle; occludent and carinal margins subparallel, the latter  $\frac{2}{3}$  as long; surface slightly convex and traversed by ribs emanating from region of umbo; ribs more conspicuous in lower half of plate; apical umbo partly overlapping occludent margin of tergum. Tergum triangular, sculptured with longitudinal ribs except for a narrow carinal portion. Upper latus appears triangular but is four sided; a faint diagonal angulation runs from umbo to carinolateral angle. Carina with broad base enclosed between carinal latera; roof flat and marked with broad 'U' shaped lines of growth; parietes well developed, smooth (Fig. 6B). Carinal latus higher than wide, lateral margin long and partly overlapped by inframedian latus; ribs radiate from umbo; while not shown in figure, carinal margins broadly interdigitating (Fig. 6B-C). Inframedian latus more than 4 times as long as broad; traversed by transverse striae; umbo at truncate apex. Rostral latus trapeziform; divided into two unequal triangular areas by a faint ridge that runs from umbo to basilateral angle. Rostrum well developed, triangular, broad above and pointed below (Fig. 6D). Peduncle short, covered with 6 rows of strong scales with projecting edges.

Labrum bullate; crest armed with 21 V-shaped pointed teeth (Fig. 6H). Palp long and narrow; proximal superior and distal margins covered with spines (Fig. 6I). Mandible with 4 teeth including the inferior angle; first tooth well separated from second (Fig. 6E); inferior angle strongly denticulate and armed with 8 pointed teeth (Fig. 6F). Maxilla I with a deep notch in middle of cutting edge; 2 long and 2 short spines above notch and 2 long and 2-3 short spines below notch; surface covered with long setae (Fig. 6G). Maxilla II triangular and covered with a few marginal setae on superior, distal and inferior margins.

Cirrus I separated from remaining cirri; posterior ramus slightly longer; segments moniliform; covered with long plumose setae (Fig. 6J). Cirrus II not modified. Cirri III-VI essentially equal in length with subequal rami. Articular areas along greater curvature with 1-2 long thin setae; interarticular areas and lateral faces naked; setation ctenopod; 2 major and 1 minor pair of setae along lesser curvature; a few short bristles at bases of these (Fig. 6K). Caudal appendage uniarticulate; shorter than first segment of pedicel of cirrus VI; anterior and posterior borders free of setae; 4-5 setae distally. Cirral counts of the holotype follow:

	I	II	III	IV	V	VI	Ca
Styx-7 680903	7	11	14	15	16	17	
Sta. 1	8	12	13	15	16	16	1
(Holotype)	7	12	14	15	15	15	
	8	10	14	14	16	17	1

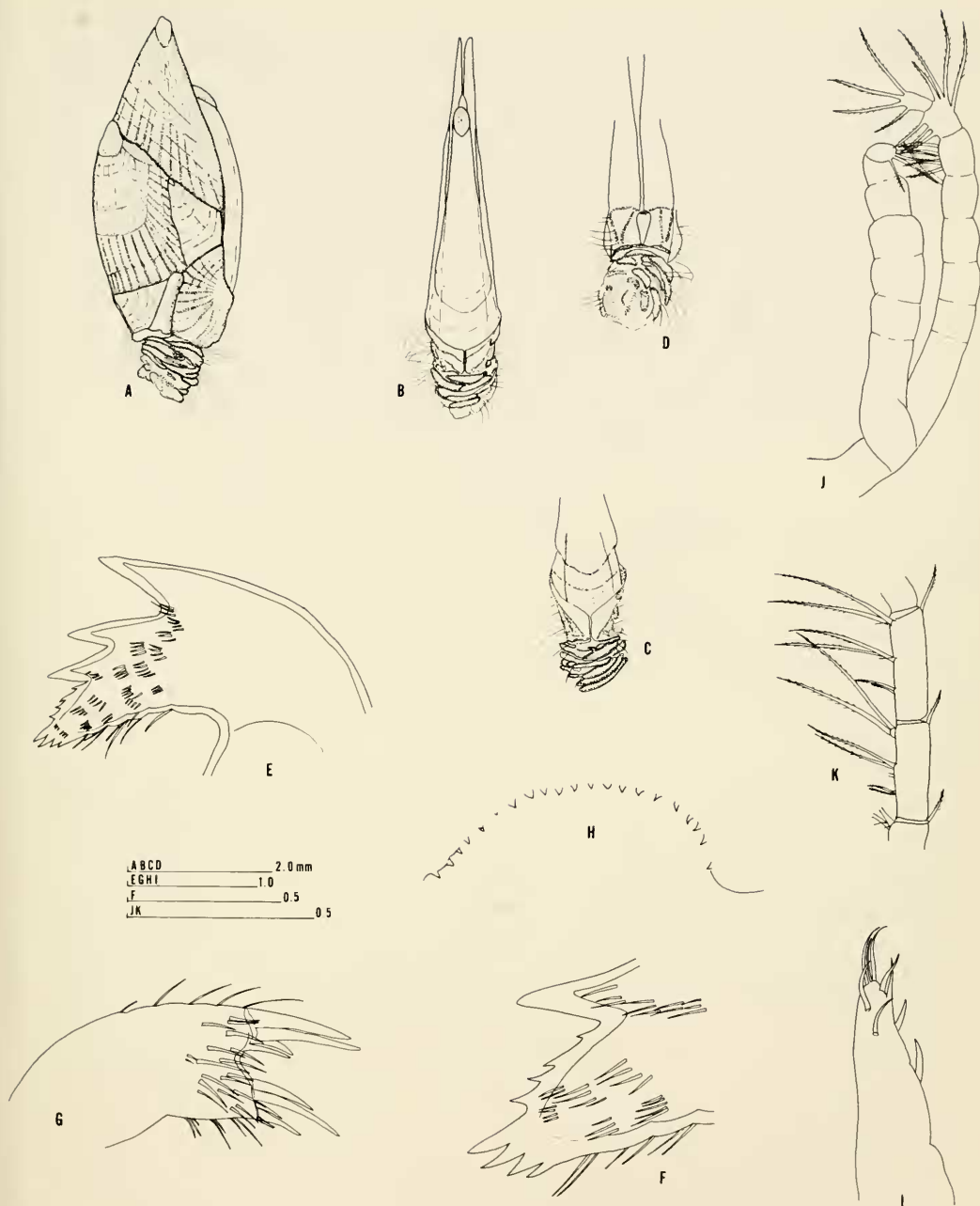


Figure 6. *Arcoscalpellum radiatum* n. sp., Holotype, Styx-7, 680903, Sta. 1, Allison Guyot. A, side views of female; B, carinal view; C, base of carina and abutment of carinal latera; D, rostrum and adjoining plates; E, mandible; F, third tooth and inferior angle of mandible; G, maxilla I; H, crest of labrum; I, palp; J, cirrus I; K, intermediate articles of cirrus VI.

*Remarks.*—*Arcoscalpellum radiatum* is related most closely to *A. pacificum* (Pilsbry), *A. chilense* (Pilsbry) (new name for *A. gracile* (Pilsbry) and *A. semisculptum* (Pilsbry)). Characters in common are an elongate capitulum, a narrow and elongate inframedian latus with an apical umbo and shorter than the carinal latus, the presence of a narrow and elongate rostrum and the possession of carinal latera which are higher than wide and interdigitating where they meet. The ornamentation of the capitular plates of *A. radiatum* recalls the condition in *A. pacificum*. However, the rostral latera of *A. pacificum* are wider than high, the

umbones of the carinal latera are at the lower  $\frac{1}{4}$  of the carinal margin (Pilsbry, 1907a), the cutting edge of maxilla I is nearly straight and the caudal appendage is five-segmented (Annandale, 1913). *Arcoscalpellum radiatum* differs from *A. pacificum* in all these characters. It differs from *A. chiliense* in the possession of longitudinal ribs on the terga and scuta, in the carinal roof being flat rather than convex, and in the inframedian latus which is proportionately much wider and decidedly higher than the adjoining rostral latus. *Arcoscalpellum semisculptum* also has an inframedian latus which is much narrower than in *A. radiatum*, but in this species the umbones of the carinal latera are placed at the lower  $\frac{1}{3}$  of the carinal margin as opposed to their distinctly medial position in the new species. The type of *A. semisculptum* came from a depth of 512 meters which is nearly one-third the depth from which the Mid-Pacific specimens were taken. Broch (1953) recorded one specimen from a depth of 1484 meters, comparable to the Pacific station. Unfortunately neither Pilsbry (1907c) nor Broch gave any details of the arthropodal structures of this species.

Also present at the same station is a small individual which has not yet developed the radial sculpture, but is in all other respects similar to the one described above.

### ***Arcoscalpellum rossi* n. sp.**

#### Figure 7

*Material*.—Styx-7, 680901 Sta. 3, Hess Guyot (174°24.8' W, 17°53.2' N), 1692-1735 m (Sigsbee beam trawl), 1 spec. Styx-7, 680903-04 Sta. 1, Allison Guyot (179°36.0' W, 18°31.0' N), 1413-1645 m (otter trawl), 2 spec.

*Depository*.—U.S.N.M. no. 140949 (Holotype, Styx-7, 680901, Sta. 1) U.S.N.M. no. 140950 (Paratypes, Styx-7, 680903-04 Sta. 1, 2 spec).

*Diagnosis* (female).—Capitulum long and narrow, composed of 14 fully calcified plates. Roof of carina flat, parietes well developed, especially towards distal half of plate. Rostrum large, ovotriangular and fully exposed. Maxilla I with notch in middle of cutting edge. Mandible with four teeth including inferior angle; upper margin of third tooth serrated. Caudal appendage of 4 segments and reaching to  $\frac{3}{4}$  height of first segment of pedicel of cirrus VI.

*Description* (female).—Capitulum long and narrow, composed of 14 fully calcified plates and sparsely covered with hairs. Plates separated by narrow chitinous interspaces and marked with faint lines of growth. Occludent margin strongly convex; carinal margin irregularly straight; apex slightly retroverted towards the carinal side (Fig. 7A).

Tergum triangular, occludent margin short and convex, scutal and basal margins almost straight, carinal margin concave for  $\frac{2}{3}$  the distance towards the carinal angle and straight thereafter. Scutum more than twice as long as broad; lateral margin sinuate just below tergotlateral angle; apex of upper latus projects towards this sinuous part; umbo apical, overlapping occludent margin of tergum. Upper latus appearing triangular but five sided. Carinal latus fully twice as long as broad; carinal margin curving out at base of carina, beyond which umbones bluntly project. Carinal latera meet and surround base of carina in form of a broad 'V' and do not interdigitate (Fig. 7C). Carina long and simply bowed; roof flat; parietes well developed towards distal half of plate (Fig. 7B). Inframedian latus rectangular, more than four times as long as broad, umbo submedial in position, slightly displaced towards distal half and slightly raised above surface of plate. Rostral latus nearly rectangular in outline, with parallel but unequal scutal and basal margins and sub-parallel lateral margins. Rostrum large, fully exposed, elongate triangular, broad above and pointed below (Fig. 7D). Peduncle short, bent at right angles to capitulum and covered with 6-8 rows of narrow elongate plates with chitinous interspaces.

Labrum bullate; crest armed with 22 teeth. Palp narrow and elongate; superior and anterior margins armed with a few spines; inferior margin with proximal short stout spine (Fig. 7E). Maxilla I with a well defined notch in middle of cutting edge, 2 long and 1-2 short stout spines above and one long and 3-5 short spines below notch (Figs. 7H, I). Maxilla II with 3 well defined lobes; marginal setae long and setulose; setae distributed in 3 clusters, those of inferior margin being segregated; lateral margins sparsely setose; maxillary lobe moderately long and cylindrical (Fig. 7J). Mandible with 4 teeth including inferior angle; second tooth twice the distance from the first than from the third tooth; upper margin of third tooth serrate (Fig. 7F); inferior angle supporting 8 long, narrow and pointed teeth (Fig. 7G).

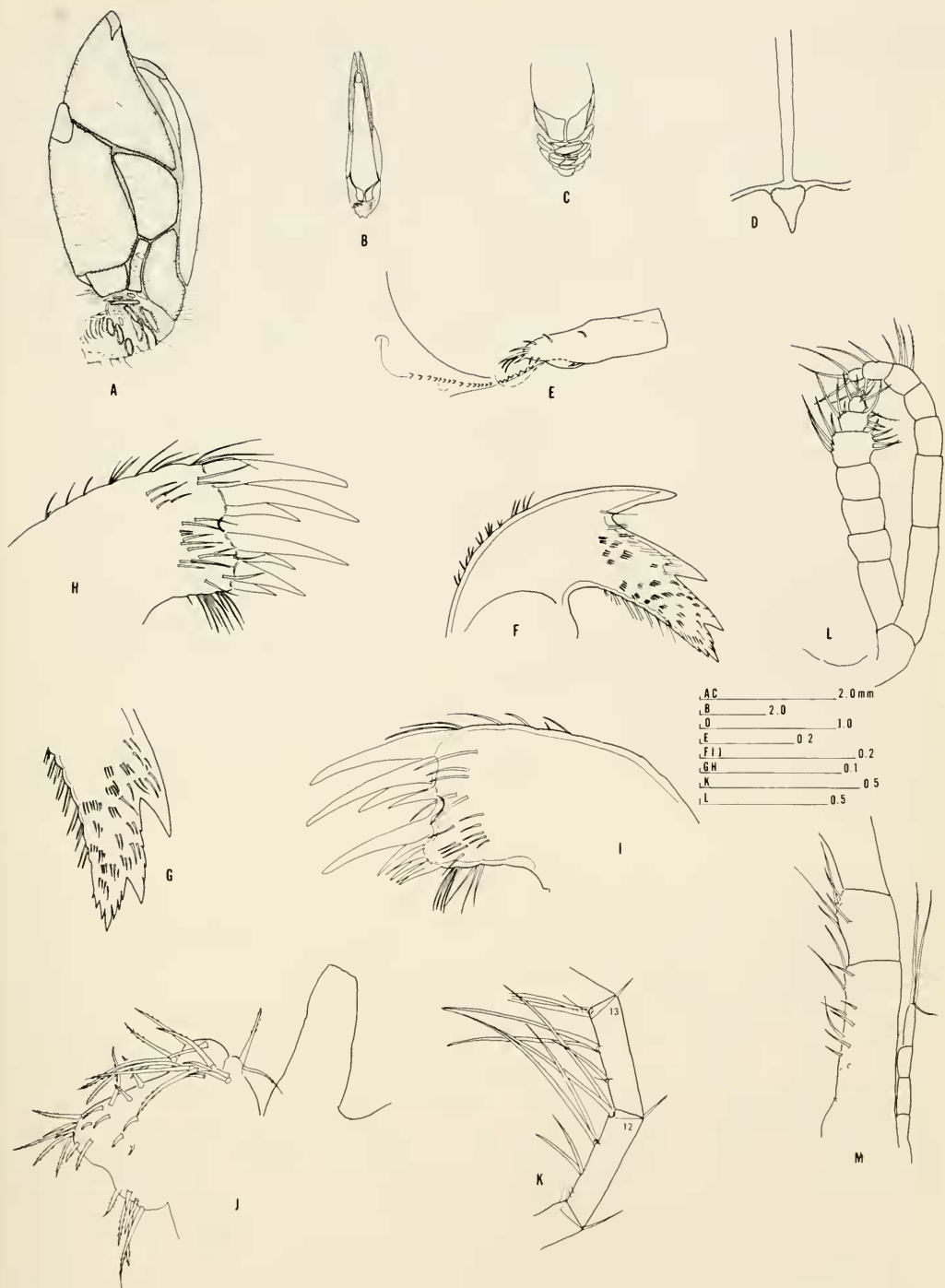


Figure 7. *Arcoscalpellum rossi* n. sp., Holotype, Styx-7, 680901, Sta. 3, Hess Guyot. A, right side view of female; B, carinal view; C, carinal latera; D, rostrum; E, crest of labrum and left palp; F, mandible; G, third tooth and inferior angle of mandible; H-I, maxillae I; J, maxilla II; K, intermediate articles of cirrus VI; L, cirrus I; M, caudal appendage.

Cirrus I (Fig. 7L) separated from the rest; cirrus II normal; articular areas along greater curvature of cirrus VI with one sharp spine; interarticular areas faintly serrated with 5-6 spines; lateral faces devoid of setae. Setation ctenopod; 2 major and 1 minor pair along

lesser curvature. Caudal appendage composed of 4 segments; reaching to  $\frac{3}{4}$  length of first segment of pedicel of cirrus VI; distal segment with 2 long and 1 short setae (Fig. 7M). Cirral counts follow:

	I	II	III	IV	V	VI	Ca
Styx-7, 680901	$\frac{7}{8}$	$\frac{12}{13}$	$\frac{15}{18}$	$\frac{18}{18}$	$\frac{18}{19}$	$\frac{18}{19}$	4
Sta. 3 (Holotype)	$\frac{1+}{8}$	$\frac{12}{14}$	$\frac{17}{15}$	$\frac{19}{17}$	$\frac{19}{19}$	$\frac{20}{18+}$	4

*Remarks.*—*Arcoscalpellum rossi* is related to *A. flavum* (Hoek, 1883:127), *A. novae-Zelandeae* (Hoek, 1883:124), *A. abyssicola* (Hoek, 1883:114), *A. minutum* (Hoek, 1883:113), *A. perlongum* (Pilsbry, 1907b:198), *A. albatrossianum* (Pilsbry, 1907c:54). Characters that unite all these species are: 1) the capitulum is elongate and narrow, the lower whorl of latera contributing in part to its lengthening; 2) a long and narrow inframedian latus with an umbo that is medial to basal.

With the exception of *A. rossi* all these species have an inframedian latus which is either hour-glass shaped or has at least a narrow constriction in the middle. *Arcoscalpellum rossi* can be separated readily from these by its rectangular inframedian latus which is not at all constricted. Further, it has a well developed rostrum that is fully exposed whereas in the others a rostrum has not been described or, if present, is of a smaller size.

In the relative proportions of the capitular plates and in the general nature of the arthropodal structures *A. rossi* shows a close resemblance to *A. albatrossianum* and *A. perlongum*. All three species have a mandible in which the upper margin of the third tooth is serrate and maxilla I has a deep notch in the middle of the cutting edge (Nilsson-Cantell, 1925; MacDonald, 1929). However, in *A. albatrossianum* and *A. perlongum* the caudal appendages reach beyond the pedicel of cirrus VI and respectively have 8 and 6 segments whereas in *A. rossi* the caudal appendage is shorter than the first segment of the pedicel of cirrus VI and has 4 segments.

The species is named for Arnold Ross, Natural History Museum, San Diego, student of barnacles, and friend.

?*Arcoscalpellum* sp.

Figure 11E-F

*Material.*—Styx-7, 680910 Sta. 5, Sio Guyot (171°05.7' E, 18°17.7' N). 1692 m (pipe dredge), broken shells.

The shell fragments from Sio Guyot, while undoubtedly belonging to a scalpellid, are too incomplete to allow positive identification and are tentatively assigned to *Arcoscalpellum* on the basis of a carina (Fig. 11F) and a scutum (Fig. 11E).

Genus *Mesoscalpellum* Hoek, 1907

*Mesoscalpellum gruvellii* (Annandale), 1906

Figures 8 and 11H-I

*Scalpellum gruvellii* Annandale 1906b:390; 1906a:141, text-fig. 4; 1907-1908, pl. 1, fig. 1, pl. II, figs. 1, 1a, 3; 1913:232; *Scalpellum gruvellii* var. *quadratum* Annandale, 1906b:391; 1907, pl. II, fig. 3; *Annandaleum gruvellii*; Newman and Ross, 1971:122; *Scalpellum chitinosum* Hoek, 1907:73 pl. VII, fig. 4; *Scalpellum imperfectum* Pilsbry, 1907c:75, pl. IV, figs. 15-18, text-fig. 30; Barnard, 1924:46; 1925:3; MacDonald, 1929:537, pl. 2, fig. 3; Broch, 1953:9; Stubbings, 1961:11, fig. 2; Zevina; 1969:67; *Mesoscalpellum imperfectum*: Newman and Ross, 1971:119; fig. 62.

*Material.*—Styx-7, 680903-04 Sta. 1, Allison Guyot (179°36.0' W, 18°31.0' N), 1429-1663 m (otter trawl), 1 spec.; 680905, Allison Guyot (179°37.1' W, 18°35.4' N), 1449-1557 m (otter trawl), several spec.

*Supplementary description* (female).—There is considerable variation in the external morphology of the large series of specimens from the Mid-Pacific (see fig. 8A-C, 11H-I). However, specimens comparable in size to Annandale's types appear identical with his descriptions. Some clarification is needed as regards the vase-shaped nature of the inframedian latus, supposedly characteristic of the genus *Annandaleum* (Newman and Ross, 1971). In *A. gruvellii*, both in the original description and in several of the specimens in the present collection the outline of this plate has the shape of an hourglass. A club-shaped ridge, with its expanded extremity, projects outwards, and it is this ridge that gives the plate its vase-like appearance, especially when seen through the semi-transparent membrane.



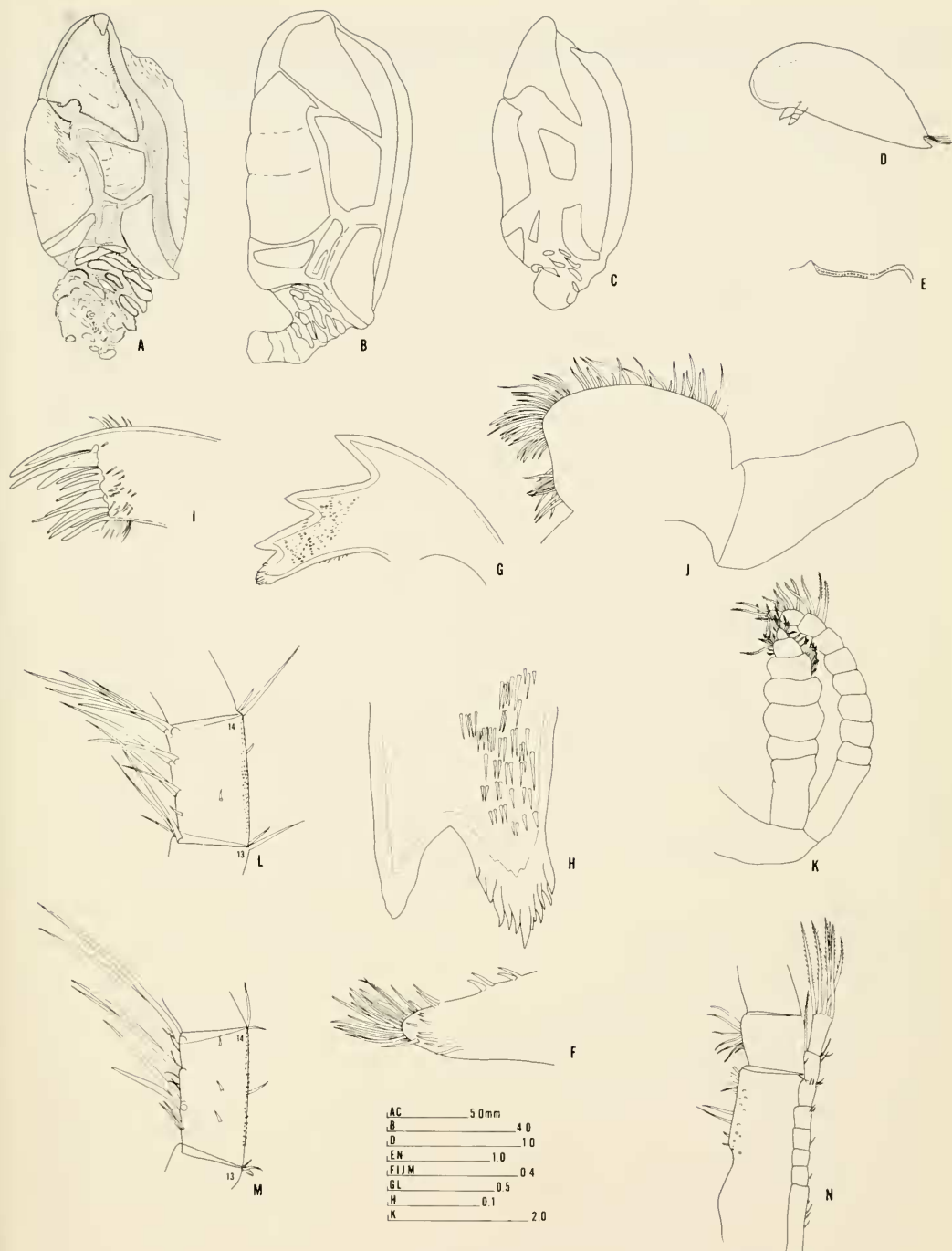


Figure 8. *Mesoscalpellum gruvelii* (Annandale), Styx-7, 680903-04 Sta. 1, Allison Guyot (A and D-N); Styx-7, 680905, Sta. 2, Allison Guyot (B-C). A-C, side views of females; D, male cyprid; E, crest of labrum; F, palp; G, mandible; H, third tooth and inferior angle of mandible; I, maxilla I; J, maxilla II; K, cirrus I; L, intermediate article of outer ramus of cirrus VI; M, intermediate article of inner ramus of cirrus VI; N, caudal appendage.

The bearing this problem has on the distribution of the genus will be taken up below, under remarks.

Annandale's descriptions of mouth parts and cirri are incomplete and are elaborated on as follows. Labrum long, triangular rather than bullate; crest armed with 40-50 bluntly

pointed teeth (Fig. 8E). Palp elongate, bluntly triangular distally; superior proximal margin with a few stout spines; distal extremity strongly spinose, lateral faces with a few spines (Fig. 8F). Maxilla I with straight cutting edge; upper margin with 1 short and 2 long spines; lower margin supporting 2 long and 4 short, stout spines (Fig. 8I). Mandible with 4 teeth including a slightly receding inferior angle; first tooth well separated from second; third tooth proximal to inferior angle (Fig. 8G); inferior angle supporting 12-13 moderately long, somewhat pointed teeth (Fig. 8H). Maxilla II triangular, lobes feebly developed; marginal setae distributed in 3 clusters; lateral faces setose; maxillary lobe elongate, broad near the base and narrow apically (Fig. 8J).

The cirri, as noted by Annandale, are devoid of pigment. Cirrus I widely separated from the rest; intermediate segments of anterior ramus protuberant, those of posterior ramus cylindrical and  $\frac{3}{4}$  as wide (Fig. 8K). Cirri II-VI increasing progressively in length and with equal or subequal rami. Greater curvatures of cirri II-VI with 2-3 rows of stiff bristles; lateral faces with 1-4 rows of setae; articular areas with a cluster of 3-5 setae; interarticular areas with 1-4 setae. Distal cluster of setae along lesser curvature of intermediate segments hypolasiopod in outer ramus and ctenopod (3 major pairs and 1 minor pair) in inner ramus; 2-3 pairs at bases of all major setae (Figs. 8L, M). Caudal appendages as long as pedicels of cirrus VI; each consisting of 8 segments; distal segment supporting 6 long setae of equal length (Fig. 8N). Cirral counts of one specimen are:

	I	II	III	IV	V	VI	Ca
Styx-7, 680903-04	$\frac{8}{11}$	$\frac{19}{22}$	$\frac{23}{24}$	$\frac{27}{28}$	$\frac{28}{26}$	$\frac{30}{28}$	8
Sta. 1	$\frac{8}{10}$	$\frac{20}{22}$	$\frac{24}{26}$	$\frac{26}{26}$	$\frac{28}{28}$	$\frac{29}{29}$	8

A male cyprid was found in a pouch on the inner side of the right scutum of one specimen. It resembles (Fig. 8D) the male cyprid of *S. gruvellii* (= *M. gruvellii*) by Stewart (1911).

*Remarks.*—Several authors expressed concern over the similarities between *Annandaleum gruvellii* (Annandale), *Mesoscalpellum imperfectum* (Pilsbry), and *M. sanctaebabarbarae* (Pilsbry), (see Pilsbry 1907c; Annandale, 1913; Barnard, 1924; Stubbings, 1961; Newman and Ross, 1971). This and related problems need clarification here. The first is with regard to the inclusion of *gruvellii*, in the genus *Annandaleum* proposed by Newman and Ross (1971) for the reception of this and three other Indo-West Pacific species. The most diagnostic characteristic of *Annandaleum* is the large and vase-shaped inframedian latus, which as far as can be judged from published figures, is present in *A. japonicum*, *A. lambda* and *A. flavum*. In *A. gruvellii*, it is not well developed and the inclusion of this species in *Annandaleum* greatly weakens the definition of this genus. Actually *A. gruvellii* has a facies similarity with members of the genus *Mesoscalpellum* and we propose that it be transferred to this genus. This greatly sharpens the distinction between the two genera.

The second problem concerns *M. gruvellii* and *M. imperfectum*. Several specimens from the Mid-Pacific collection show a point to point similarity with the description of *M. gruvellii* (Annandale, 1906b) and there is no doubt that the specimens before us belong to this species. However, the arthropodal structures of the Mid-Pacific specimens are almost identical with those of the paratypes of *M. imperfectum* figured by Newman and Ross (1971, text-fig. 62). Therefore we believe that *imperfectum* and *gruvellii* are the same species, a synonymy that has been suggested before.

This leaves us the question as to the status of *M. sanctaebabarbarae*. Newman and Ross pointed out several differences in the anatomy of *M. imperfectum* (= *M. gruvellii*) and *M. sanctaebabarbarae*. We have had the opportunity to examine closely the soft parts of the latter species from the San Diego Trough, which confirm that the differences are consistent, with one exception. The setation of the distal cluster of the intermediate articles of the outer rami of cirrus VI is said to be ctenopod in the paratypes whereas it is distinctly hypolasiopod in the specimen from the San Diego Trough. The importance of this difference remains to be determined and in the light of other differences we are inclined to continue to recognize the two species.

With the transfer of *gruvelii* to *Mesoscalpellum* and the recognition of *M. imperfectum* as a synonym of *M. gruvelii*, the genus and the species take on a world wide distribution (Indian, Atlantic and Pacific oceans).

Family Poecilasmatidae Annandale, 1909  
 Genus *Megalasma* Pilsbry, 1907c  
 Subgenus *Glyptelasma* Pilsbry, 1907c  
*Megalasma (Glyptelasma) pilsbryi* Calman, 1919

Figure 9

*Megalasma (Glyptelasma) pilsbryi* Calman, 1919:363, fig. 1A-C, fig. 2; Nilsson-Cantell, 1928:20, fig. 9A-E; 1938:10.

*Material*.—Styx-7, 680905 Sta. 2, Allison Guyot (179°37.1' W, 18°35.4' N), 1445-1557 m (otter trawl), 10 spec., all attached to *Arcoscalpellum michelottianum* and *Mesoscalpellum gruvelii*.

*Supplementary description*.—The external morphology of our specimens agrees with the description given by Calman (1919). The base of the carina is produced into two teeth on the inner side (Fig. 9C). In the present specimens the basal margin of the scutum and carina meet at an angle of more than 90° whereas in Calman's specimens these are shown to meet at right angles. This character varies with growth.

Nilsson-Cantell (1928) gave brief descriptions of the mouth parts. More detail of the trophi and cirri is in order. Labrum bullate, slightly broader than long and bluntly triangular anteriorly; anterior margin and surface covered with tufts of 2-6 fine, short hairs; crest armed with 35 small, stout and somewhat pointed teeth (Fig. 9F). Palp broad proximally and bluntly conical distally; superior margin free of setae; inferior and distal margins bordered by long plumose setae; lateral faces setose (Fig. 9F). Mandible with 5 teeth including inferior angle; upper margin of fourth tooth serrate; surface profusely covered with long thin spinules some of which cross the cutting edge; superior and inferior margins bordered by short, thin hairs along the entire length (Fig. 9G); inferior angle tridentate, the teeth being short and pointed (Fig. 9H). Maxilla I with cutting edge concave above and strongly convex below, without a well defined notch, 2 long and 1 short spine above; the convex lower portion supports a set of 14-15 short and long spines, and superior and inferior margins as well as surface covered with short hairs (Fig. 9I). Maxilla II triangular, higher than wide; superior lobe well developed, distal and inferior lobes feebly so; marginal setae distributed in three clusters, those of superior and distal lobes separated by a naked superior margin (Fig. 9J).

Cirrus I widely separated from cirrus II; anterior and posterior rami equal in length and composed of 9 and 10 segments respectively; segments of anterior ramus 1¼-1½ times broader than those of posterior (Fig. 9E). Cirrus II, 1½ times longer than cirrus I; cirri III-VI equal in length with equal rami and composed of a rather constant number of segments. Articular areas along greater curvatures with 2-3 long and 1-2 short setae; interarticular areas and lateral faces devoid of setae; setation ctenopod; 3 major pairs and 1 minor pair along lesser curvature; 1-3 short bristles at bases of major pairs (Fig. 9K). Caudal appendage uniaarticulate, short, about ⅓ height of first segment of pedicel of cirrus VI; anterior and posterior margins bordered with small and inconspicuous spinules; distal end broad, with 8 short to long plumose setae (Fig. 9L). Penis large, proximally broad, gradually tapering to a blunt apex; surface covered with long thin setae which are sparsely distributed for a greater length of the organ but are more profuse and conspicuous towards the distal end. A single pair of rather short, slender filamentary appendages are present on dorsum of prosoma near its posterior margin (Fig. 9M), as described and figured by Calman (1919). Cirral counts of the dissected specimen follow:

	I	II	III	IV	V	VI	Ca
Styx-7, 680905	9	15	19	18	19	19	
Sta. 2	10	16	19	19	19	20	1
	9	17	19	19	19	20	
	10	16	19	19	19	18	1

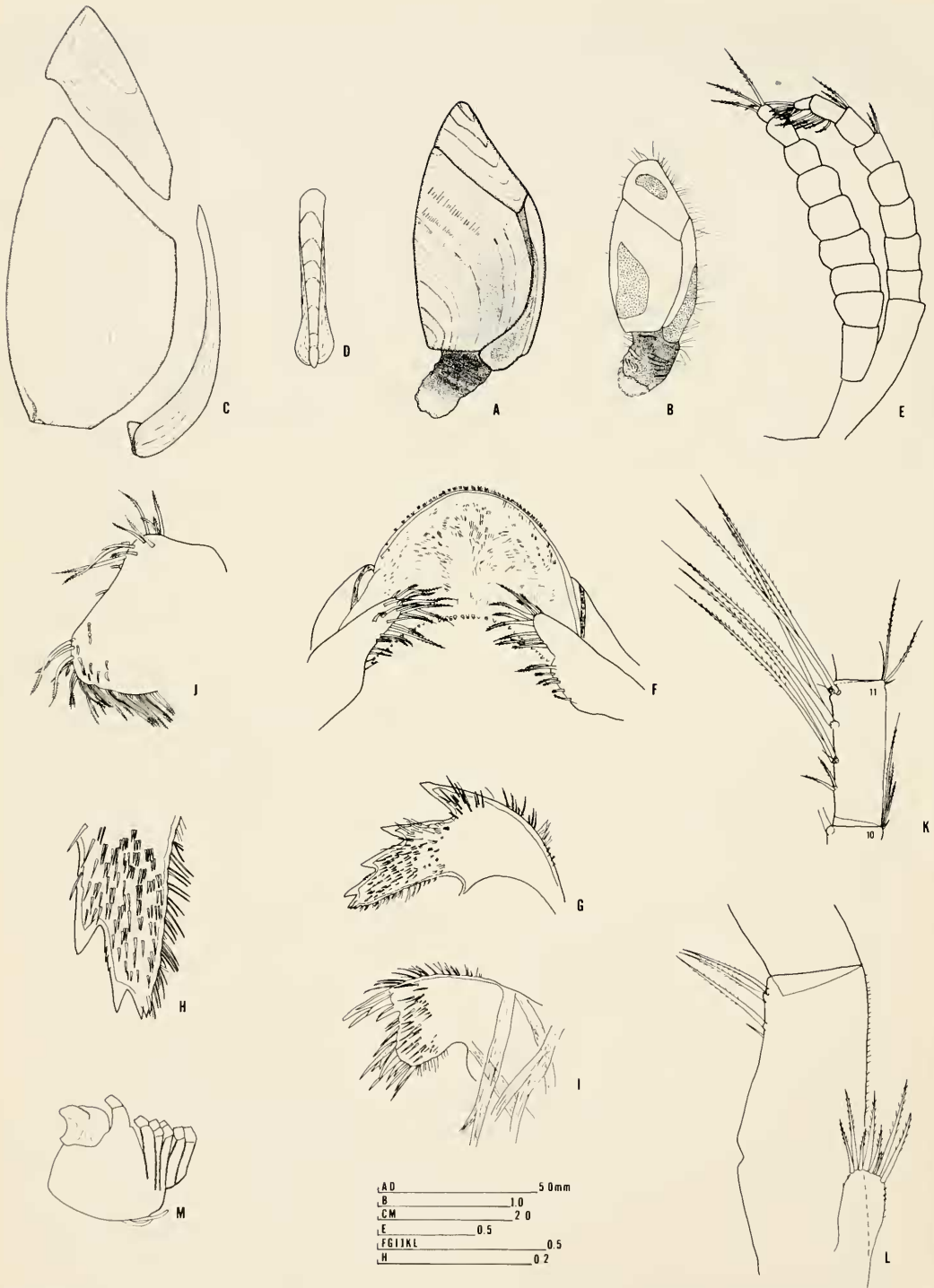


Figure 9. *Megalasma (Glyptelasma) pilsbryi* Calman, Styx-7, 680905, Sta. 2, Allison Guyot. A-B, right side view of hermaphrodites; C, inner view of disarticulated shells; D, outer view of carina; E, cirrus I; F, labrum and palps; G, mandible; H, third and fourth teeth and inferior angle of mandible; I, maxilla I; J, maxilla II; K, intermediate articles of cirrus VI; L, caudal appendage; M, prosoma and filamentary appendages.

*Remarks.*—Pilsbry (1907c,d) and Calman (1918b, 1919) discussed the status and definitions of the genus *Megalasma* and its subgenera *Megalasma* s.s. and *Glyptelasma*. The specimens from the Mid-Pacific are clearly referable to *Glyptelasma* because the basal margin of

the scutum forms a distinct angle with the occludent margin, and also by the weak sculpture of the plates. The configuration and relative proportions of the capitular plates and the general structure of the trophi and cirri are in agreement with the description of *Megalasma* (*Glyptelasma*) *pilsbryi*. The bathymetry is also similar. The figures and descriptions given by Nilsson-Cantell show that the crest of the labrum has about 50 teeth, the rami of cirrus I have 9 and 11 segments and the posterior cirri have 23-24 segments. In contrast, the crest of the labrum of the Mid-Pacific specimen supports 35 teeth, the rami of cirrus I have 9 and 10 segments respectively and the posterior cirri are composed of 18-20 segments. It is likely that allometry may account for these differences, Nilsson-Cantell's specimens being larger (capitular height: 20 mm) than the Mid-Pacific example (capitular height: 11 mm).

*Megalasma pilsbryi* is closely related to *M. annandalei* Pilsbry. Calman (1919) and Barnard (1925) recognized this, but both authors advocated their retention as good species. Calman stated that *M. pilsbryi* differs from *M. annandalei* "in having no sudden widening of the sides of the carina and no excavation of the adjacent sides of the scutum, as well as in the thick cuticle covering the valves . . ." Furthermore the intermediate segments of cirrus VI of *M. pilsbryi* support 3 major pairs and one minor pair of setae along the lesser curvature whereas in *M. annandalei* there are 4 major pairs and 1 minor pair (Pilsbry, 1907, pl. V, Fig. 14).

The Mid-Pacific specimens were found attached to *Arcoscalpellum michelottianum* and *Mesoscalpellum gruvelii*. Nilsson-Cantell (1928) collected this species from *Scalpellum vetulinum* (= *A. michelottianum*) and *S. alcockianum* (= *A. alcockianum*).

Suborder Verrucomorpha Pilsbry, 1916

Family Verrucidae Darwin, 1854

Genus *Verruca* Schumacher, 1817

Subgenus *Altiverruca* Pilsbry, 1916

***Verruca* (*Altiverruca*) *allisoni* n. sp.**

Figure 10

*Material*.—Styx-7, 680901. Hess Guyot (174°24.8' W, 17°53.2' N), 1,718-1,770 m (Sigsbee beam trawl), 3 spec., on trochid gastropods; Styx-7 680915 Sta. 1, Darwin Guyot, (171°16.5' E, 21°53.3' N), 1,300-1,353 m (rock dredge), 2 spec., on manganese fragment.

*Depository*.—Holotype U.S.N.M. no. 140951 (Styx-7, 680915); Paratypes U.S.N.M. no. 140952 (Styx-7, 680901).

*Diagnosis*.—Distinguished from all other *Altiverruca* in having 7 rather than 3 or 4 interlocking teeth forming the suture between the carina and rostrum.

*Description*.—Shell white, without persistent yellow cuticle. Suture between rostrum and carina formed by numerous interdigitating ribs (Fig. 10H). It can be deduced from successive growth lines that the number of ribs increases throughout life. In the holotype this number has increased from as few as 3 or 4 to 7. Sutures formed by rostrum overlapping fixed scutum and by carina overlapping fixed tergum; sutures simple except carinal margin of fixed tergum is ala-like. Suture between fixed tergum and fixed scutum formed by an ala-like margin on former and radius-like margin on latter (Fig. 10G). Parietal portion of fixed tergum interdigitates between radius-like and parietal portions of fixed scutum.

Movable tergum and scutum articulated by the interdigitation of proximal portions of their apico-basal ridges (Fig. 10H). Supplemental ridges parallel main ridges on scutal side of the movable tergum, and the rostral portion of the movable scutum is ornamented by longitudinal lines (Figs. 10K, L).

Crest of labrum supports numerous teeth, nearly 80 in the paratype; palps pointed, sparsely covered with short strong setae (Fig. 10A). Mandible with 3 teeth, not including lower cutting edge and inferior angle; upper margin of third tooth and lower cutting edge serrate; inferior angle of several stout spines (Fig. 10B). First maxilla with group of long strong spines above and below well developed notch; inferior angle supporting few short, bifid spines (Fig. 10C). Second maxilla notched and sparsely covered with setae (Fig. 10D).

Second cirri resemble more the first than the succeeding pairs. Their rami are relatively short, subequal and uncoiled. Intermediate articles of posterior pairs ctenopod, each supporting 1 long plumose and 1 short simple pair of setae, and often 1 minute simple seta, along the lesser curvature (Fig. 10F). Caudal appendages of 6 to 8 segments and less than

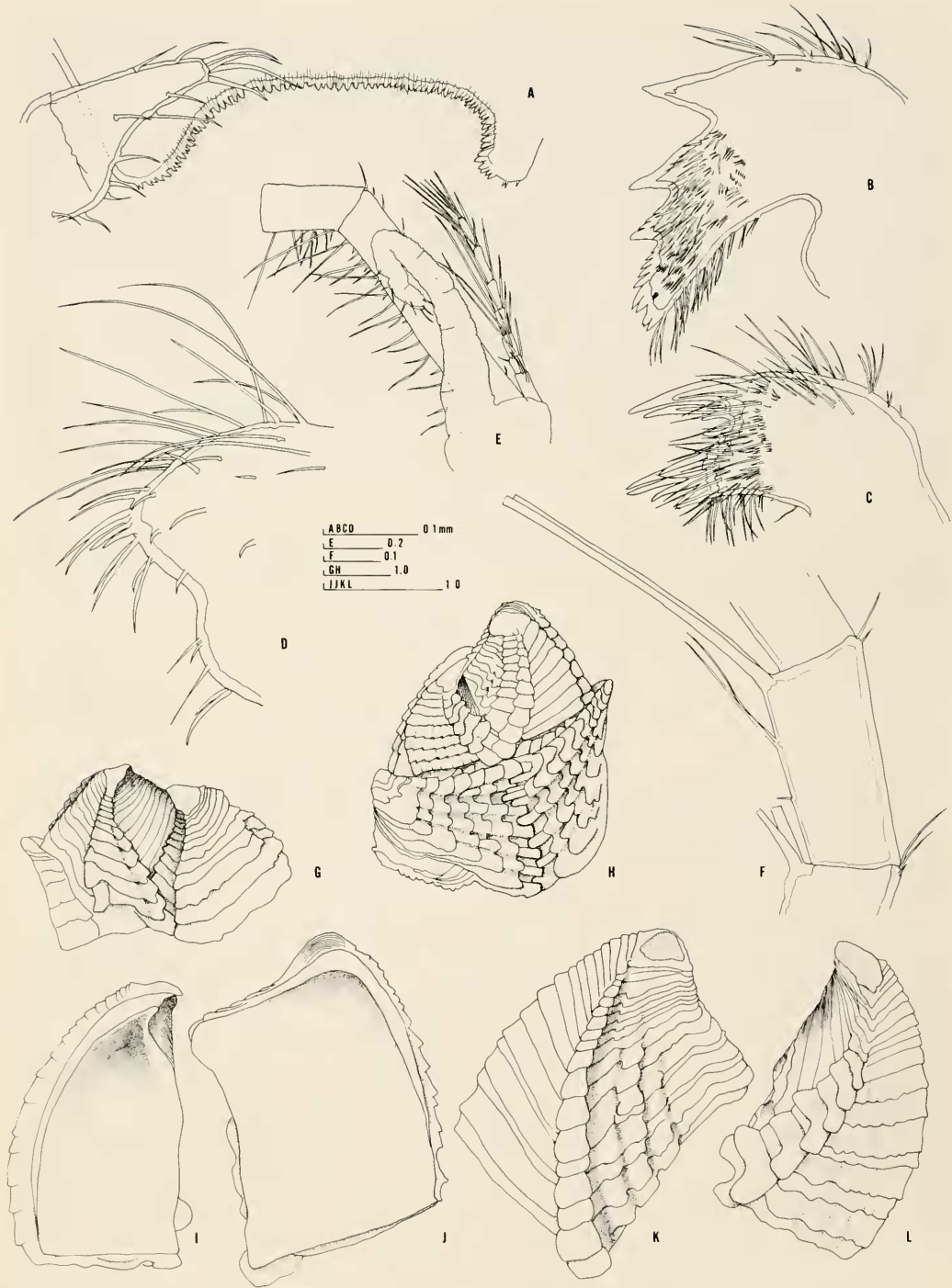


Figure 10. *Verruca (Altiverruca) allisoni* n. sp. A-F and I-L, Holotype. A, labrum and palp, left palp removed; B, mandible; C, maxilla I; D, maxilla II; E, pedicle of cirrus VI supporting penis and caudal appendage; F, intermediate article of cirrus VI; G, lateral view of entire specimen illustrating relationship of carina, fixed tergum and fixed scutum; H, lateral view of entire specimen illustrating relationship of movable terga and scuta with the carina and rostrum; I and L, interior and exterior views of the movable scutum respectively; J and K, interior and exterior views of the movable tergum respectively.

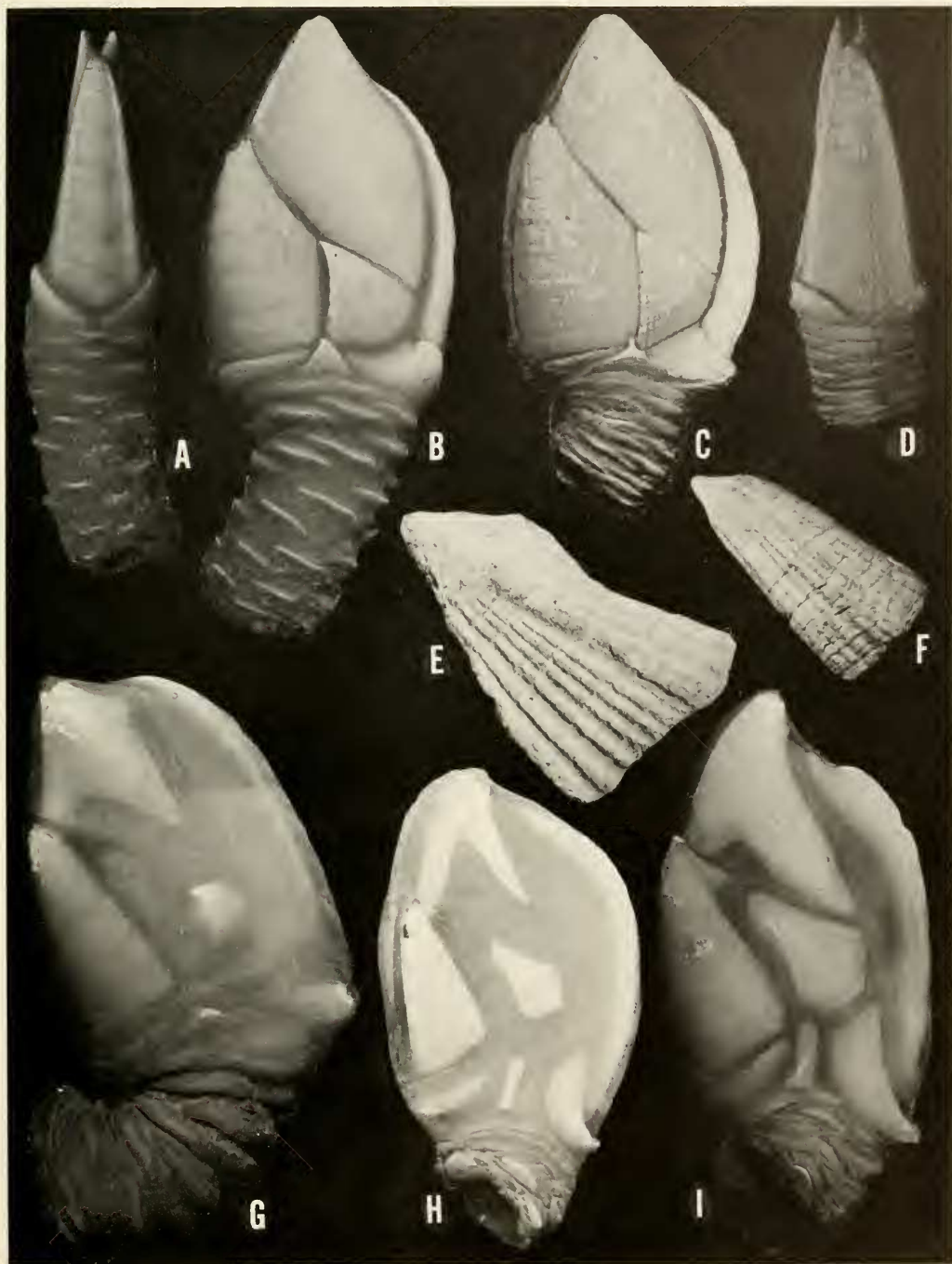


Figure 11. A, *Arcoscalpellum michelottianum* (Seguenza), carinal view of female X 1.42; B, right side view of the same individual X 1.6; C, *A. hawaiiense* (Pilsbry), right side view of female X 1.7; D, carinal view of the same individual X 1.4; E, ? *Arcoscalpellum* sp. scutum X 4.2; F, ? *Arcoscalpellum* sp., carina X 3.4; G, *A. alcockianum* (Annandale), right side view of hermaphrodite X 1.57; H, *Mesoscalpellum gruvelii* (Annandale), right side view of female X 1.4; *Mesoscalpellum gruvelii* (Annandale), right side view of female X 3.9 (A-D and H from Styx-7, 680905 Sta. 2, Allison Guyot; E-F from Styx-7, 680910 Sta. 5, Sio Guyot; G and I from Styx-7, 680903-04 Sta. 1, Allison Guyot).

the length of the basal segment of the pedicel of cirrus VI; the penis relatively short, provided distally with a few short seta (Fig. 10E). Cirral counts for three specimens follow:

	I	II	III	IV	V	VI	
Hess Guyot Styx-7, 680901 (Paratype)	$\frac{9}{8}$	$\frac{7}{8}$	$\frac{13}{16}$	$\frac{22}{23}$	$\frac{22}{-}$	$\frac{24}{26}$	7
Hess Guyot Styx-7, 680901 (Paratype)	$\frac{11}{9}$	$\frac{9}{11}$	$\frac{13}{16}$	$\frac{17}{21}$	$\frac{20}{15}$	$\frac{17}{19}$	8
Darwin Guyot Styx-7, 680915 Sta. 7 (Paratype)	$\frac{6}{6}$	$\frac{9}{10}$	$\frac{13}{14}$	$\frac{17}{16}$	$\frac{17}{-}$	$\frac{19}{-}$	6

*Remarks.*—*Verruca (Altierruca) allisoni* is similar to *V. (A.) cristallina* Gruvel, 1907 from the East Indies, *V. (A.) gibbosa* Hoek, 1883 which is nearly cosmopolitan, and *V. (A.) regularis* Nilsson-Cantell 1929 from the Nicobar Islands. It differs from the first in having 7 rather than 3 or 4 interlocking teeth between the rostrum and carina, in lacking multiple interlocking ridges between the suture of the fixed tergum and scutum and in lacking the small beaded ridges along the scutal margin of the rostrum. It differs from the second and third in having 7 rather than 4 interlocking teeth between the rostrum and the carina, in having the movable scutum with longitudinal markings and in having a fixed scutum lacking an ala-like rostral margin.

The major difference between this and other species of *Altierruca* is the large number of interlocking teeth between the rostrum and carina. In fact this same difference separates this species from all other *Verruca* except *V. (?Rostratoverruca) dens* Broch 1931, *V. (R.) intexta* Pilsbry 1912, *V. (?R.) koehleri* Gruvel 1907, *V. (?R.) nexa* Darwin 1854 and *V. (Verruca) scrippsae* Zullo 1964. Broch's illustration indicates there are about 6 interlocking teeth between the rostrum and carina, essentially as in the present species. Pilsbry (1907c), discussing Darwin's species, says that there are 7 ribs on the carina interlocking with the rostrum. It is curious that the new *Altierruca* should be so similar in this regard to these members of *Rostratoverruca*. One might suspect that the subgeneric diagnosis was wrong. However there is no question that the apex of the rostrum is not separated from the scutal margin of the plate, as it is in *Rostratoverruca*. The similarity to *V. (V.) scrippsae* is only with regard to the carino-rostral suture; the complex interlocking sutures between the fixed scutum and the rostrum and the fixed tergum and the carina are wholly lacking in *V. (A.) allisoni*.

#### ACKNOWLEDGMENTS.

This paper is a contribution from the Scripps Institution of Oceanography and was supported in part by National Science Foundation grants GB-7596 and GB-30908X.

#### LITERATURE CITED

- Allison, E.C., J.W. Durham, and L.W. Mintz  
1967. New Southeast Pacific Echinoids. California Acad. Sci. Occ. Pap. 62: 1-23.
- Annandale, N.  
1905. Malaysian barnacles in the Indian Museum, with a list of the Indian Pedunculata. Mem. Asiatic Soc. Bengal. 1(5): 73-84.  
1906a. On the Cirripedia. Rept. Pearl Oyster Fisheries, Govt. Ceylon 5(31): 137-150.  
1906b. Natural History Notes from the R.I.M.S. ship "Investigator." Ser. III. No. 12. Preliminary report on the Indian stalked barnacles. Ann. Mag. Nat. Hist. 7(17): 389-400.  
1907-1908. Illustrations of the Zoology of the R.I.M.S. ship "Investigator." Crustacea (Entomostraca), pls. I-IV.  
1909. An account of the Indian Cirripedia Pedunculata. Part I. Family Lepadidae (sensu stricto). Mem. Indian Mus. 2: 61-137.  
1913. The Indian barnacles of the subgenus *Scalpellum*. Rec. Indian Mus. 9(4): 229-236.  
1916. Three plates to illustrate the Scalpellidae and Iblidae of Indian Seas, with synonymy and notes. Mem. Indian Mus. 6(3): 127-131.



- Barnard, K.H.  
 1924. Contribution to the crustacean fauna of South Africa. No. 7 Cirripedia. Ann. South African Mus. 20: 1-103.  
 1925. Report on a collection of Cirripedia from South African waters. Rept. Fish. Mar. Biol. Survey IV(6), Cape Town: 1-5
- Broch, H.J.  
 1931. Indomalayan Cirripedia. Papers from Dr. Th. Mortenson's Pacific Expedition. 1914-1916. Vidensk. Meddel. Dansk Naturh. Foren. 91: 1-146.  
 1953. Cirripedia Thoracica. Danish-Ingolf Exped. 3(14): 1-17.
- Calman, W.T.  
 1918a. On barnacles of the genus *Scalpellum* from deep-sea telegraph cables. Ann. Mag. Nat. Hist. 9(1): 96-124.  
 1918b. The type specimens of *Poecilasma carinatum* Hoek. Ann. Mag. Nat. Hist. 9(4): 401-408.  
 1919. On barnacles of the genus *Megalasma* from deep-sea telegram cables. Ann. Mag. Nat. Hist. 9(24): 361-374.
- Darwin, C.  
 1854. A monograph on the subclass Cirripedia, with figures of all the species. The Balanidae, the Verrucidae etc. Ray Soc., London. 684 p.
- Gruvel, A.  
 1907. Cirripèdes operculés de le l' Indian Museum of Calcutta. Mem. Asiatic Soc. Bengal. 2(1): 1-10.
- Hamilton, E.L.  
 1956. Sunken Islands of the Mid-Pacific Mountains. Geol. Soc. America Mem. 64: 1-97.
- Hoek, P.P.C.  
 1883. Report of the Cirripedia collected by H.M.S. Challenger during the years 1873-1876. Rept. Scient. Res. Voyage H.M.S. Challenger, Zool. 8 (4): 1-169.  
 1907. The Cirripedia of the Siboga Expedition. Cirripedia Pedunculata. Siboga Expedite. 31a. 1-127.
- Hubbs, C.L.  
 1959. Initial discoveries of fish faunas on seamounts and offshore banks in the Eastern Pacific. Pacific Sci. 13(4): 311-316.
- Karig, D.E., M.N.A. Peterson and G.G. Shor  
 1970. Sediment-capped guyots in the Mid-Pacific Mountains. Deep-Sea Research 17: 373-378.
- Lonsdale, P.F., W.R. Normark and W. A. Newman.  
 1972. Sedimentation and erosion on Horizon Guyot. Geol. Soc. America Bull. 83: 289-315.
- Menard, H.W.  
 1964. Marine Geology of the Pacific. McGraw Hill Co., New York.
- MacDonald, R.  
 1929. A report on some cirripedes collected by the S.S. Albatross in the eastern Pacific during 1891-1904. Bull. Mus. Comp. Zool. Harvard 49(15): 527-538.
- Newman, W.A. and A. Ross.  
 1971. Antarctic Cirripedia. Antarctic Research Series 14:1-257. Amer. Geophys. Union.
- Nilsson-Cantell, C.A.  
 1925. Neue und wenig bekannte Cirripeden aus den Museen zu Stockholm und zu Uppsala. Ark. Zool. 18 A(3): 1-46.  
 1928. Studies on Cirripedes in the British Museum (Natural History). Ann. Mag. Nat. Hist. 10(2):1-39.  
 1929. Cirripeden des Genus *Verruca* der Deutschen Tiefsee-Expedition auf dem Dampfer "Valdivia" 1898-1899. Zool. Jahrb. Syst. 58: 459-480.  
 1931. Cirripedes from the Indian Ocean and Malay Archipelago in the British Museum (Natural History), London. Ark. Zool. 23 A(18): 1-12.  
 1938. Cirripedes from the Indian Ocean in the collection of the Indian Museum, Calcutta. Mem. Indian Mus. 13(1): 1-81.
- Pilsbry, H.A.  
 1907a. Hawaiian Cirripedia. Bull. U.S. Bureau Fish. 26: 181-190.  
 1907b. Cirripedia from the Pacific Coast of North America. Bull. U.S. Bureau Fish. 26: 193-204.  
 1907c. The barnacles (Cirripedia) contained in the collections of the U.S. National Museum. U.S. Natl. Mus. Bull. 60: 1-122.  
 1907d. Notes on the cirriped genus *Megalasma*. Proc. Acad. Nat. Sci. Philadelphia 59: 408-416.  
 1911. Barnacles of Japan and Bering Sea. Bull. U.S. Bureau of Fish. 29: 59-84.  
 1912. Diagnoses of new barnacles from Philippine Archipelago and China Sea. Proc. U.S. Natl. Mus. 42: 291-294.  
 1916. The sessile barnacles (Cirripedia) contained in the collections of the U.S. National Museum, including a monograph of the American species. U.S. Natl. Mus. Bull. 93: 1-366.
- Schumacher, C.F.  
 1817. Essai d'un nouveau Système des habitations des Vers testacés. Schultz, Copenhagen.
- Seguenza, G.  
 1873-1876. Ricerche palaentologiche intorno ai Cirripedi Terziarii della provincia di Messina. Con appendice intorno ai Cirripedi viventi nel Mediterraneo, e sui fossili terziarii dell'Italia meridionale. Pt. I, Balanidi e Verrucidi, 1873; Pt. II, Lepadidi, 1876. Atti Accad. Pontaniana, Napoli. 10: 265-481.
- Stewart, F.H.

1911. Studies in postlarval development and minute anatomy in the genera *Scalpellum* and *Ibla*. Mem. Indian Mus. 3(2): 33-51.
- Stubbings, H.G.  
1961. Cirripedia from the Tropical West Africa. Atlantide Rept. 6: 7-41.
- Zevina, G.B.  
1969. Cirripedia Thoracica. The Biology of the Pacific Ocean, book II pt. I, Deep-Sea Bottom Fauna, V.G. Kort. ed., Inst. Okeanol. Akad. Sci. U.S.S.R.: 66-68.  
1972. Benthic Lepadomorpha (Cirripedia Thoracica) from the Southeast Pacific. Crustaceana 22(1): 39-63.
- Zullo, V.A. R.F. Kaar, J.W. Durham and E.C. Allison.  
1964. The echinoid genus *Salenia* in the Eastern Pacific. Palaeont. 7(2): 331-349.
- Zullo, V.A. and W.A. Newman.  
1964. Thoracic Cirripedia from a Southeast Pacific Guyot. Pacific Sci. 18(4): 355-372.

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